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ORIGINAL ARTICLES.

I.—On 'Cleat' in Coal-seams.

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(PLATE III.)

MY interest in cleat was first aroused by the study of the Geological Survey memoir on the coals of South Wales (1908), from which it became clear to me that the subject of the origin of anthracite was intimately bound up with that of cleat. The object of the present communication is, however, not directly connected with the anthracite question, upon which I hope to have something to say when researches upon which I am engaged with Mr. E. J. Edwards, M.Sc., of Cardiff, have reached a more advanced stage.

The 'cleat', or system of joints traversing coal-seams, has strangely escaped investigation by any British geologist during the past half-century. But for brief and often conflicting references to the phenomenon in textbooks, among which those in Professor J. Geikie's *Structural and Field Geology* and Dr. Walcot Gibson's *Geology of Coal Mining* must be signalized as the most valuable, and for more or less casual allusions to it in papers by mining engineers, it might well be imagined that all recollection of the existence of such a structure had died out. The word 'cleat', or any *alias* by which it might be indicated, finds no place in the Index to the first fifty volumes of the Q.J.G.S., nor does it appear in the "Geological Literature added to the Society's Library". A search through about thirty memoirs of the Geological Survey relating to coal-fields failed to yield a word upon the subject.[1] Yet two quotations from earlier sources will suffice to show that problems of surpassing interest are presented by the disposition of the cleat in some British coal-fields. Jukes in his *Manual of Geology* (1862), p. 212, says: "The large smooth vertical surfaces [in a block of coal] are known by the name of 'the face', 'the slyne', or 'the cleat' of the coal in different districts, the more interrupted set being sometimes spoken of as 'the end' of the coal. The 'face of the coal' is the most necessary thing to attend to in laying out the working galleries or gate-roads of a coal-mine, since it retains its parallelism over very large areas." In a footnote he adds: "*In inquiring of a collier in the Nottinghamshire coalfield in the year 1838 as to the direction of 'the slyne' (as the face is there called), I was informed that it faced 'two o'clock sun, like as it does all over the world, as ever I heered on', by which I understood that the sun*

[1] Since this was written I have learned that in the South Wales Coal-field cleat is known as 'slips': with this clue I found an allusion to 'slip-cleavage' in the memoir above mentioned. It stated that there was none in anthracite.

would shine directly upon it at two o'clock in the afternoon in an open work or that the planes ran about W.N.W. and E.S.E., and were persistent in their direction in all my informant's district at all events." He quotes John Phillips's Report on Cleavage and Foliation in Rocks, etc., in the B.A. Report for 1856, and I give the passage *in extenso*:—

"§ 11. *The Cleat in Coal.*

"In the northern coal districts of England, and in other tracts, there exists, besides the lamination parallel to the bounding surfaces of the beds, a series of approximate, often nearly vertical divisional surfaces, along which the coal admits of easy fissility. This structure is called cleat, and it is of the greatest importance in coal working, since parallel to it the headways are driven in the 'post and stall' workings of Northumberland and Durham, and parallel to it the 'banks' are wrought in the 'long wall' and 'bord and end' systems of Yorkshire and Derbyshire. Cleat is little affected by fractures or undulations of the strata. It has usually one persistent course across a large district,—the same direction often obtains in neighbouring districts, and even prevails over the whole of a great Carboniferous region. Thus in Northumberland and Durham the cleat runs most generally to the north-west (true); its 'strike' is in that direction. The most general strike of the beds is to N.N.E. The same direction of cleat is prevalent in Yorkshire and Derbyshire, and this whether the beds strike eastward, as near Leeds and Sheffield, or southward, as near Huddersfield and Chesterfield. The same direction prevails in Lancashire."

In reading this pregnant passage one scarcely knows which feeling is uppermost—admiration for the marvellous industry and insight of Phillips, or astonishment that his generalization attracted so little of the attention of either his contemporaries or successors. So far as the Yorkshire Coal-field is concerned, his statement of fact is endorsed by all mining engineers with whom I have spoken, and I shall add some corroboration of my own.

The particular aspect of the subject to which I wish now to apply myself is the absolute independence of the cleat in coal-seams, not only to the lie of the rocks, but also to the jointing of the measures in immediate association with them. This relation is not explicitly indicated by Phillips, though it is perhaps implied by his statement that the direction of cleat maintains its constancy despite diametric changes of dip.

I will first substantiate the constancy of cleat by a few examples taken at random. All the bearings are *magnetic*.

Southowram, near Halifax, cleat . . .	N. 17° W.
,, ,, joints in roof	N. 63° W.
,, ,, ,,	N. 39° E.
Robin Hood Quarry, near Wakefield, cleat . .	N. 43° W.
Wheldale and Fryston, cleat	N. 22° W.
Allerton Bywater, cleat	N. 25° W.
Whitwood, cleat	N. 28° W.

The total variation of direction in these readings is 26°, or taking N. 30° W. as the direction most commonly observed in this coal-field the deviation is 13° to the west and 13° to the east.

The Southowram set of readings (one of several in the same colliery) is interesting, as showing that actually the jointing in the very roof of the seam is as divergent from the cleat as it is possible to be. A better case is, however, afforded by Robin Hood Quarry, midway betwixt Leeds and Wakefield. At this place a great pit has been excavated in the Middle Coal-measures for the extraction of shale for brick-making, and, as it is on the site of an old shallow coal-mine, not only was the shaft opened out, but many of the old roads in the famous Haigh Moor Seam, with their primitive oaken timbering, are now laid open to the day. The seam itself, roughly 3 ft. 6 in. in thickness, has been bared over a considerable area, and the unusual experience is afforded of studying one of the principal and quite the most interesting seams in this coal-field in open sections and plan. The surface of the seam shows very perfectly the direction of the cleat, and in the accompanying Plate III, from a photograph by Mr. A. Gilligan, the disposition of this structure and its relation to the dip of the seam and to the jointing of the measures are shown in a very instructive and convincing manner. The top 'lift' of the seam has been removed over a space in the foreground, and the recent rains have formed a pool of water, the general direction of the margin of which defines the strike; the rail placed perpendicularly to this gives the dip. The further side of the pool is a hewn edge of the coal, bearing no specific relation to the structure.

The coal-seam shows the two sets of joints known to the Yorkshire miner as the 'bord' and 'end'. There appear to be differences between local usages in the application of these terms, but a clear account of the custom in Yorkshire, as well as of the way in which the cleat affects the laying out of a colliery, will be found in a paper by Sir William E. Garforth.[1]

The 'bord' in this seam is formed by a very strongly marked and persistent system of joints, in the picture seen running along the right-hand margin of the pool and almost directly away from the observer. The faces are very smooth and lustrous, and are perpendicular to the bedding; they are in general parallelism, with very little convergence. In the most superficial layer of the seam the intervals are very small, not more than three-quarters of an inch. In the next layer the unjointed intervals are 2 inches in breadth, and in the massive seam below they are still larger. It may be said in general terms that the interval is roughly proportional to the thickness.

The 'end' is much less regular, and the direction varies from one pair of 'bord' joints to the next, so that the seam breaks with a ragged 'end'. These differences determine in a large number of cases the mode of laying out of a colliery: in the present instance the roads are bounded by 'bord' faces.

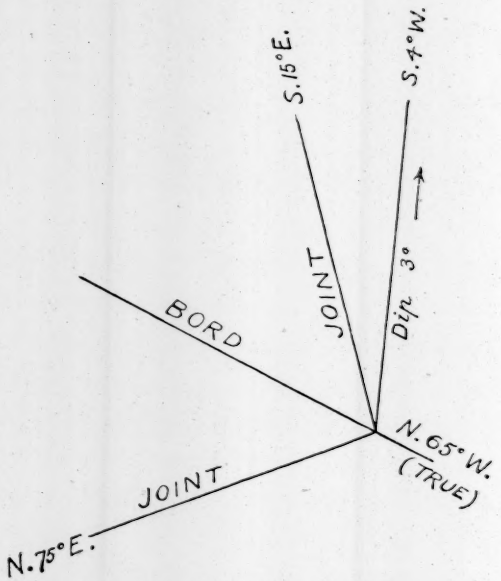
The surface of the seam is marked in some places by the imprint of large trees, and I observed one stigmarian impression. The imprints that I noticed were laid out about E. 10° N.

The beds resting immediately upon the seam are very argillaceous shales with many ironstone nodules with plant-remains, and they are

[1] Trans. Manchester Geol. and Min. Soc., vol. xxviii, p. 203, 1903.

followed by more shales with a couple of small coal-seams, but near the top of the picture can be seen the rectangular salients and re-entrants of a boldly jointed bed of hard sandstone. While the shales are shattered by irregular joints in all directions and in various azimuths, and therefore are valueless for comparison with the cleat, the sandstones afford trustworthy data. The photograph shows quite clearly that the prolongation of the cleat would almost exactly bisect these joints (see Figure). The case is quite typical of the unrelated disposition of the cleat to the jointing of the measures.

I refrain for the present from entering into any discussion of the cause of the cleat, but there is one question that seems to admit of an answer or at least a suggestion even at this early stage of the investigation, and I venture to deal with it now in the hope that I may elicit from some reader with a knowledge of lignite beds abroad information of which I am much in need.



The question I refer to is—Why does the jointing in the coal take a course absolutely unrelated to that of the enclosing measures? The first proposition I would advance is the obvious one that the two sets were produced by forces operating in different directions and at different times. The cleat would, I imagine, be produced first—otherwise it is difficult to understand why a fragile substance like coal should have escaped shattering by the force that jointed the other rocks, whereas if it had already acquired a cleat it might yield to later strains or stresses without the production of a fresh system of fractures.

Pursuing this inquiry further, we should ask to what property coal, or the peaty mass out of which the coal was later formed, owed

its facility for early jointing. I adopt the following as a working hypothesis to guide me in further researches.

When our Coal-measures were first laid down they would consist of a series of incoherent sands and muds, and this uncompacted condition may have persisted for a very long period, so long as pressures were not excessive and no cementation took place; even surviving considerable tectonic disturbances, if we may judge by the condition of the Bovey Tracey Beds. The peats, however, would be subject to changes dependent upon processes entirely innate: the gradual loss of volatile constituents or at least the resolution of the carbon compounds into new groupings and the conversion of the mother-substance of the coal into lignite. This has happened, as Principal Clayden informs me, to the logs and trunks in the Bovey Tracey deposits, and I have observed the same thing in the coaly lenticles at Alum Bay. Professor J. J. Stevenson, in the latest of his brilliant and closely reasoned memoirs on the formation of coal-beds,[1] cites two instances of Quaternary peats passing into lignite.

In this condition the coal substance would be brittle and liable to joint. Now, let a deforming stress or strain be applied, or perhaps a wave or tremor sweep the country, and the sheet of brittle material would be shattered, while the unconsolidated sands and clays would of course be unaffected.

The idea that the initiation of joints, as it were the pulling of the trigger, is due to seismic tremors is urged by W. O. Crosby, and at a recent meeting of the Yorkshire Geological Society Mr. Harker remarked that the regularity of the joints in sedimentary rocks favoured the view that they were due to some kind of wave action. In no sedimentary rocks is there greater regularity than in coal.

I have no desire to press this or any other hypothesis, but I would remark that, though evidence is not lacking of considerable tectonic movements having taken place during the deposition of the Coal-measures adjacent to the Pennine area, it seems to me impossible to connect them with this widespread phenomenon that cuts, at all angles, the lines of structure of the country.

In conclusion, may I beg for information from those readers of the Geological Magazine who have opportunities for observing lignite beds occurring in uncompacted sediments regarding the development of cleat.

II.—The Geology of South Georgia.[2]

1. Notes on the Geology of South Georgia.

By D. Ferguson, Mem. Inst. M.E., F.R.G.S.

THE island of South Georgia is nine hundred miles S. 80° E. from the Falkland Islands. The coastline of the island is rock-bound and more or less precipitous, and there is neither open beach nor

[1] Proc. Amer. Phil. Soc., lii, 208*c*, p. 33.

[2] A more detailed account of the geology of South Georgia, and of its rocks and fossils, will appear in one of the volumes on the results of the Scotia Expedition, which are now being published by Dr. W. S. Bruce.

detrital flat on its outward margin. A narrow valley, a morainic flat, inside Cumberland Bay, runs up 4 miles to a glacier, and there are other patches of morainic material, marking the recession of the glaciers. Leith Harbour is one of these, and Elsie and Adventure harbours, originally enlarged by the ice into one channel, have been separated into two safe anchorages by morainic material.

The Allardyce range of mountains forms the longitudinal axis of the island, running approximately north-west and south-east. The highest crests of the range, Mount Paget, the Sugar Loaf, and the Nordenskjöld Peak, are near the centre of the island. The outer coast escarpments are succeeded inland by rocky heights, having ice in every hollow. The central range, except on steep rock escarpments and splintery crests, is covered with permanent ice-fields and snow.

The greatest length of the island is about 110 miles, and its greatest breadth across Cumberland Bay and Mount Paget is just over 29 miles. The height of Mount Paget is given as 6,000 feet above sea-level on the charts of the island, but it was found to be 8,383 feet, from a base-line which was in part measured, and for the larger part the mean of a series of speed runs by a whaling steamer in Cumberland Bay, as no other method was available at the time. There can be little doubt, however, that Mount Paget is much higher than 6,000 feet, which has probably been stated as an approximation in the absence of accurate determination instrumentally.

Geological Literature.—Captain Cook called the island Georgia in honour of King George III. He sailed down the north-east coast from Willis Island to Cooper Island at the south-east extremity. We owe to this explorer the names of many of the promontories and bays, first discovered by him and now familiar to navigators in the South Atlantic. Possession Bay was named by Captain Cook on account of his landing there and taking possession of the island in the name of King George III. He refers to rocky islets and rocky hillocks, but does not give any details of geological structure. He makes the interesting statement that he did not find a stream of fresh water on the whole coast, and that only along the escarpments of the north-eastern coast is there warmth enough to melt the snow. In recent years the whaling industry has obtained ample supplies of the purest fresh water, flowing from the base of the glaciers on the north-east coast.

Captain James Weddell [1] also visited the island, and described it as so deeply indented that boats are frequently transported overland from one coast to the other.

Dr. Otto Nordenskjöld [2] states that the general features of the South Georgian landscape are similar to those of Spitzbergen. Mountains and fiords follow each other in the same way, but the fells of South Georgia rise from the coast, in most places, precipitously to almost inaccessible ridges. He describes this island, situated in lat. 54° S., as having glaciers as large as those of Spitzbergen in lat 80° N. He found traces everywhere in Mai Viken, Cumberland

[1] J. Weddell, *A Voyage towards the South Pole*, pp. 50–4.
[2] O. Nordenskjöld, *Antarctica*, p. 340.

Bay, of a former ice-covering, with morainic gravel and beautifully scored glacier stones, which proved that an immense mass of ice had once filled the entire valley. During a visit he paid in 1902 to Moraine Fiord in Cumberland Bay, he discovered the first fossil found in South Georgia embedded in an enormous block of stone.

K. Fricker [1] in his account of the island adopts the view that it is connected with the Cordilleras of South America and with the Sandwich Islands. He considers the outline, the narrow extended form, and the deep fiords prove the fact that in South Georgia we have a portion of a broken and submerged mountain chain. He quotes the geological features described by Hans Thürach, the geologist of the German Scientific Expedition of 1882. Near Royal Bay the rocks are clay-slates alternating with phyllite-gneiss, upon which follows clay-slate alternating with quartz-slate, and he says that huge banks of shale or diabase-tuff and sandstone occur near the Weddell glacier.

Dr. Fritz Heim,[2] geologist to the German Antarctic Expedition (1911) commanded by Lieutenant Filchner, states that the rocks at Royal Bay are chiefly phyllite, schists, and tuffs (?) of unknown age; and that the rocks have a north-west and south-east strike and southerly dip. According to his observations, the entire north coast, with the exception of Royal Bay and part of Cumberland Bay, appears to be built up of interstratified dark-grey to bluish-grey schists and greenish tuffs. The rocks of Royal Bay are of different appearance from all seen on the northern coast, and also from those in the inlets east of Royal Bay. He considers that South Georgia is a folded mountain chain, and that the general strike of the fold probably coincides with the strike of the island. Volcanic rocks were discovered from Novosilski Bay round to Drygalski Fiord on the south-eastern end of the island. In Larsen Harbour pebbles of crystalline rock of dioritic habit were found, and at Glosarczyk Fiord numerous blocks of acid rock of granitic type occurred everywhere in the moraines. He gives a qualified support to the view that South Georgia is allied to the Patagonian Cordilleras.

Rock Series exposed.—Unlike most small islands in the Atlantic, South Georgia is mainly a mass of sedimentary rocks. Its coastline for the greater part is formed of stratified rocks, generally indurated, and in places somewhat altered by pressure-metamorphism.

With the exception of two older but attenuated exposures of sedimentary rocks in Cumberland Bay and Cape George Harbour, the stratified rocks belong to one great series, which can be conveniently divided into three divisions, upper, middle, and lower. The largest and most impressive exposures of the series is in Cumberland Bay, but it stretches from Royal Bay to Cape North. Only a patch of the upper division of the series is seen near New Fortune Bay, and west of Cape North it comes in again, but the middle and lower divisions are well exposed from Royal Bay to Cape North.

[1] K. Fricker, *The Antarctic Regions*, 1900.

[2] F. Heim, "Geologische Beobachtungen über Süd-Georgien. Geologie der Deutschen Antarktischen Expedition": Zeit. Ges. Erdk. Berlin, 1912, No. 6.

The three divisions may be collectively called the Cumberland Bay Series, and divided into upper, middle, and lower divisions. The older rocks exposed in Cumberland Bay and Cape George Harbour, and separated from the Cumberland Bay Series by a well-defined unconformability, we have named the Cape George Harbour Series.

Cumberland Bay Series.—The upper, middle, and lower divisions of this series include all the stratified rocks of Royal Bay, New Fortune Bay, part of Cape George Harbour, and much the largest part of Cumberland Bay, the whole of Stromness Bay, Possession Bay, and on to the north-western extremity of the island at Bird Island. It also includes the stratified rocks from Bird Island and Cape Weddell along the south-west coast to Annenkov Island and Novosilski Bay.

The Upper Division of the Cumberland Bay Series.—The upper beds of the upper division have a creamy-white colour, which easily differentiates them from the middle and lower divisions of the series. These are succeeded by blue and purplish-coloured shales, which continue down to the upper beds of the middle division, which are whitish, and gradually change to a characteristic reddish-brown colour.

The rocks of this division when freshly fractured are of a grey colour, and but little different in texture or composition from those of the reddish-brown middle division underlying them. They are crystal-tuffs, grey grits, fine-grained greywacke, and slaty shales. They are in some cases coarser than the rocks of the two lower divisions, and the dark or black shales, strongly evident in the lower division and frequently seen in the middle division of the series, are only meagrely, if at all, present in the upper division.

The total thickness of the upper division can only be estimated provisionally at 1,500 feet. There are no higher horizons seen on the island, and consequently it is a denuded upper surface of the upper division that is exposed.

The upper division is well developed on Bird Island on the north-western extremity of the coast, and at Cape Weddell and Adventure Bay. It extends pretty generally as a fringe along the southern coast, including Cape Demidov and Cape Nunez, and on to Novosilski Bay. Annenkov Island is mainly formed of it, and so also is Cooper Island, off the south-eastern coast.

The Middle Division of the Cumberland Bay Series.—The middle division is easily distinguished by the reddish-brown colour of the rock exposures composing it. The colour is superficial, as the rocks are generally of a grey colour when freshly fractured.

The rocks of the middle division are more or less indurated, due to folding movements. They are highly siliceous, and while some of them are fine-grained others are gritty. There are still coarser sediments, which may be regarded as fine conglomerates, with very small rounded pebbles. Interbedded with them are black shales, not of great thickness in any one bed. The crystal-tuffs also occur in some quantity.

The thickness of the middle division cannot be less than 3,000 feet, and may be much greater.

The middle division of the Cumberland Bay Series is extensively developed along the north-east coast of the island. It extends more or less continuously from Cape North to Cape Charlotte on the southern shore of Royal Bay, and extends south-east to the isolated rocks north of Cooper Island, which have been named after Lieutenant Filchner. It forms the crests of the Allardyce Range, and occupies the higher ground of all the bays and fiords from Cape North to Cape Charlotte. It gives the characteristic reddish-brown colour to the rocks along the north-eastern coast. It extends south-east of Cape Charlotte, and west of Cape North for some distance, gradually disappearing under the rocks of the upper division at Bird Island and Cooper Island. It forms the crests of Mount Paget, the Sugar Loaf, and the Nordenskjöld Peak, 8,383, 7,779, and 7,760 feet respectively above sea-level. The bedding of the rocks of the middle division is extremely well marked, and several of the wall-like escarpments on the shoulders of Mount Paget resemble the rock escarpments of Table Mountain at Cape Town.

The middle division must extend along the south-eastern coast of the island for a great part of its length along the higher ground, eventually disappearing near sea-level under the upper division.

The Lower Division of the Cumberland Bay Series.—The lower division is formed of dark or black gritty shales and greywackes. Dark or black fissile shales reach a considerable thickness, and collectively they are the predominant body in the division. They alternate with gritty and fine-grained arenaceous shales, and coarser gritty shales which may be regarded as greywacke, with a few crystal-tuffs. There is much felspathic material in rounded and angular grains in the greywacke, and their prevailing grey colour, contrasted with the black of the shales, gives a distinguishing shade to the division.

The total thickness of the division is not disclosed in any of the exposures seen, as they invariably descend below sea-level, and the full thickness is not seen, but so far as can be judged, the lower beds seen amount to about 1,200 feet.

The lower division of the Cumberland Bay Series occupies a fringe of the lower ground near sea-level from Royal Bay to Port Gladstone, Possession Bay. In Royal Bay, Cumberland Bay, Stromness Bay, and Possession Bay, it can be easily seen coming in below the middle division and underlying it conformably. Its base has not been exposed; the lowest exposures are seen in Royal Bay, where it is permeated with crystalline quartz in a network of veinlets in very fissile black shales. Subsequent to the disposition of secondary quartz, earth-movements have crumpled the beds.

In the black shales of this division in Moraine Fiord, Cumberland Bay, there is an intrusion of diabase. It was probably intruded during the deposition of the rocks of the middle division, and was contemporaneous with volcanic eruptions which took place when the lower beds of that division were laid down. There is much volcanic debris and tufaceous material in the beds of the middle division, and their red, rusty-brown colour is very probably due to the decomposition of trachytic lavas.

Cape George Harbour Series.—The rocks of this series are only seen in Cape George Harbour and in Cumberland Bay. They are separated in both places by a well-marked unconformity from the rocks overlying them. They were probably folded before the denudation which shaped the old land surface had begun to operate.

At Cape George Harbour they are overlain unconformably by the middle division of the Cumberland Bay Series. They descend below sea-level in Cape George Harbour and in Cumberland Bay, and do not rise more than 500 feet above it. In the glacier glen to the north-west off Cape George Harbour they are over 500 feet thick.

Rock Series exposed: Distribution.—The total thickness of the various series of stratified rocks is only provisionally estimated. They are not likely to be less than the estimate given here, but may on further investigation exceed it considerably, especially the middle series. Our present estimate is—

	feet	
Upper Division of Rocks	=1,500	Cumberland Bay Series.
Middle ,, ,,	=3,000	
Lower ,, ,,	=1,200	
Unconformability.		
Greenish-grey siliceous slates	= 500	Cape George Harbour Series.
Total thickness exposed	6,200	

There is such a marked difference between the greenish-grey siliceous slates and the three divisions of rocks above shown, that the unconformability which separates two geological periods probably indicates a considerable break in time.

Tectonic Geology.—The character of the rocks of the South Orkney Islands is strikingly similar to that of the three series which form the main mass of South Georgia. During the examination of South Georgia the writer obtained, through the courtesy of the Manager of the Falkland Whaling Company, which was operating in the South Orkneys, ten samples of the rocks of Washington Strait, Coronation Island. They are very similar to those of South Georgia, and the similarity was noted by Dr. Harvie Pirie, who saw them in the Geological Department, Glasgow University. Dr. Harvie Pirie was the geologist to the *Scotia* Antarctic Expedition of Dr. Bruce, and during it studied the geology of the South Orkneys.

South Georgia is a ridge mainly of stratified rocks, with its longitudinal axis identical with the general strike of the rocks. It has parallel faults on either slope of the ridge, letting down the rocks to the north-east and the south-west. The evidence of faulting is proved by the middle division of the Cumberland Bay Series occupying the crest of Mount Paget with a slight south-westerly dip, while the upper division forms the coastline at sea-level on the southern side of the island, and is seen in a few straggling beds on the northern coast near New Fortune Bay. The rocks, moreover, have been greatly crumpled and contorted. The axis of the present Allardyce Range, the central framework of South Georgia, is parallel to the general strike of the sedimentary rocks, of which it is mainly formed.

Along the north-eastern coast of South Georgia there has been in places considerable crumpling and contortion of the rocks, principally of the middle division of the Cumberland Bay Series. King Edward's Cove, Cumberland Bay, Leith Harbour, Stromness Bay, and Possession Bay afford good evidence of the folding and crumpling of the rocks. The direction of thrust is from the north-east.

Professor J. W. Gregory has kindly examined the fossils brought home by the writer from South Georgia, and Mr. G. W. Tyrrell has kindly undertaken the description of the rocks. The fossils were all found, with one exception, on the beach where Leith Harbour turns round into Nansen Harbour. The one solitary exception was found on the beach at King Edward's Point, Cumberland Bay, and was apparently a fucoid, similar to those found at Leith Harbour. The whole of the fossils were obtained from the lower division of the Cumberland Bay Series. That specimens may be found in the same division in other parts of the island is highly probable. Leith Harbour was well searched because it was near the writer's head-quarters and easily accessible.

The finding of an undoubted fossil in the middle division of the Cumberland Bay Series in Prince Olaf's Harbour (Port Gladstone), Possession Bay, by the German Antarctic Expedition, is very important, and will no doubt be described by Dr. Heim at an early date. The writer was privileged to see the specimen, which was very kindly sent over to Glasgow from Heidelberg at the request of Professor Gregory.

In conclusion, the writer would like to put on record the generosity of Messrs. Chr. Salvesen & Co., the well-known shipowners of Leith, and of Mr. Theodore E. Salvesen, the member of the firm who specially directs their extensive whaling industry in South Georgia, South Shetlands, and the Falkland Islands. Messrs. Chr. Salvesen and Co. are the lessees of the minerals and mining rights on all the British islands in the South Atlantic outside the Falkland Islands. They have not, however, confined themselves to their own special interests, but have assisted and encouraged the elucidation of the interesting geological problems presented in that outlying portion of the empire. The rock and fossil specimens brought home from South Georgia have been presented by Messrs. Salvesen to the Geological Department, Glasgow University, and the Scottish Oceanographical Laboratory, Edinburgh.

2. Preliminary Note on the Rocks of South Georgia.

By G. W. Tyrrell, A.R.C.S., F.G.S.

Cumberland Bay Series: *Upper Division.*—This consists largely of hard, coarse, compacted crystal tuffs, dark-grey or black in hand-specimens, and resembling coarse greywackes. In thin section they contain fragments of trachytic lavas, and detached crystals of orthoclase and oligoclase in a paste of minutely crystalline material mixed with much indeterminate matter. Iron-ores and ferro-magnesian minerals are rare. In some of the rocks andesitic and

latitic fragments are dominant, and occasional fragments of yellowish glass enclosing euhedral orthoclase are seen. Many of the rocks have suffered some degree of scapolitization. The tuffs pass into siliceous greywackes still with some recognizable volcanic material, and are interbedded with fine banded mudstones which appear to represent volcanic muds. Radiolaria have been recognized in these rocks as well as in the tuffs. The mudstones occasionally become somewhat laminated and pass into black shales. An imperfect cleavage traverses many of these rocks at a high angle to the bedding. These tuffs doubtless represent the interbedded 'diabas-schalstein' of Thürach.[1]

The *Middle Division* of the Cumberland Bay Series consists mainly of cleaved mudstones and siliceous shales or fine-grained grits, with a few bands of compact dark limestone, and one or two crystal tuffs, similar to those of the Upper Division. In thin section many of the grits are highly sheared, and a lamination has been set up parallel to the plane of shearing. The laminæ are frequently streaked with carbonaceous material and wind around uncrushed 'augen' of quartz. The more shaly bands are finely puckered and folded, and are traversed by quartz veins. Some of them contain a development of secondary mica. Rocks intermediate between shale and grit—siliceous slate or argillaceous grit—are common, and are frequently banded with alternations of more sandy and more shaly material. Most of these rocks are dark in colour and are distinctly cleaved. Some of the mudstones, however, are very hard and cherty, and almost devoid of cleavage-planes. The limestones are generally well cleaved. Only one shows traces of organic structures. Others contain a quantity of volcanic ash, or a considerable development of angular quartz chips, and are to be regarded as calcareous tuffs and grits.

The *Lower Division* of the Cumberland Bay Series consists of very similar types of rocks to the above, but exhibiting a higher grade of metamorphism. The mudstones are here transformed to black graphitic slates, which pass into phyllites by an increasing development of secondary mica on the cleavage-planes. Associated with these are highly sheared argillaceous grits, showing good augen texture in thin section. This association is probably the phyllit and phyllit-gneiss of Thürach. Less cleaved and altered mudstones are to be correlated with his thonschiefer. The slates and grits frequently occur in thin alternating bands, which show fine folding in the quartzose and extraordinary strain-slip and puckering in the argillaceous layers. Crystal tuffs, similar to those in the Upper and Middle Divisions, are also to be found amongst the rocks assigned to this division, especially at Port Gladstone, Cumberland Bay. One of these contains Radiolaria. A sheared limestone from Moraine Fiord is included in the collection.

Cape George Series.—Only four specimens of this series occur in the collection. They consist of grey, phyllitic, siliceous slate and black slate, much crushed and veined by quartz, otherwise not very different from the lower part of the Cumberland Bay Series.

[1] H. Thürach, "Geognostische Beschreibung der Insel Süd-Georgien": Internat. Polarforschung, 1882-3. Die deut. Exped., vol. ii, No. 7, p. 116, 1890.

Igneous Rocks.—Apart from the crystal tuffs described above, only two specimens of igneous rocks are found in the collection. One is a whitish, veined, altered rock, intrusive in the black shales of the Lower Division of the Cumberland Bay Series. This appears to be a coarse diabase or ophitic gabbro. In thin section it shows large plates of comparatively fresh colourless augite, penetrated by laths of decomposed felspar. There is also highly altered interstitial felspathic material with leucoxenic patches representing iron-ores. The other specimen was obtained from the moraine at the head of Moraine Fiord. This is a quartz-monzonite-porphyry with phenocrysts of oligoclase-andesine, orthoclase, and hornblende in a microcrystalline quartzo-felspathic ground-mass.

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3. The Geological Relations of South Georgia.

By J. W. Gregory, D.Sc., F.R.S.

THE special interest of the island of South Georgia depends on the evidence it promises as to the geological history of that part of the Southern Ocean which lies south of the South Atlantic. According to the well-known views of Professor Suess, South Georgia is on a continuation of the mountain line of the Andes, which at the southern end of South America bends eastward along the northern margin of Drake's Sea and continues 30° to the east, where it turns southward; it completes a great horseshoe-shaped course by passing through South Georgia and returning westward through the South Orkneys to Grahamland.

The geology of South Georgia has remained but little known. The first important contribution was made by Thürach, a member of the German South Polar astronomical expedition of 1882–3. According to Thürach[1] the island consists of a series of metamorphic rocks ranging from granular gneiss to clay-slate, and of beds of diabase tuff. The granular gneiss was only found as a shore pebble, but the inference that it came from the island was natural. The main rock series collected by Thürach includes a 'phyllite-gneiss' containing tourmaline, apatite, iron-ores, and andalusite; the prevalent rocks are phyllites and clay-slates, with which are interbedded some granular limestones, calc-phyllites, and quartzites. According to Thürach, there is a complete passage from the phyllitic gneiss to the slates,[2] and his illustrations[3] show that the rocks are very crushed and crumpled. The abundant diabase and tuffs recorded by Thürach suggested that South Georgia had been an active volcanic centre, and Gunnar Andersson's identification of some of the igneous rocks as porphyrite (i.e. altered andesite) was in favour of South Georgia having been part of the Andean line. Thürach obtained no evidence as to the age of the rocks, and the first fossil from the island was collected by the Swedish expedition. Dr. Otto

[1] H. Thürach, "Geognostische Beschreibung der Insel Süd-Georgien": Internat. Polarforschung, 1882–3. Die deut. Exped., vol. ii, No. 7, pp. 109–66, 1890.

[2] Ibid., p. 131.

[3] Ibid., pp. 154, 157, 158.

Nordenskjöld kindly tells me that this fossil has been identified as a *Posidonomya* and as probably Mesozoic. This conclusion recalls Darwin's view of the Cretaceous age of the similar clay-slates of Tierra del Fuego.

The *Posidonomya* was found in phyllitic rocks in Cumberland Bay, and further to the west, on the same part of the northern coast, Dr. König, of the German Antarctic Expedition under Lieutenant Filchner, found a fossil which Dr. Fritz Heim, the geologist of the expedition, identified as part of an Ammonite. The fossil is badly preserved; it has been submitted by Professor Salomon to Professor Pompeckj, who says that it *may be* an *Acanthoceras* and may be 'Kreide'. Professor Salomon has kindly given us the opportunities to see this specimen in Glasgow, and its matrix agrees closely with the rocks collected from the same locality by Mr. Ferguson; they come from the middle part of the Cumberland Bay Series and are largely composed of volcanic debris.

The preliminary paper in which Dr. Heim[1] has announced the discovery of this fossil shows that South Georgia contains a varied series of rocks; for in addition to the slates and tuffs described by Thürach, Dr. Heim records, from widely separated localities, boulders of granitic and dioritic rocks and aplite; and he discovered at the south-eastern end of the island a centre of 'alt-vulkanischer' basic eruptives, including diabase and melaphyre-like rocks. On the general conclusions as to the relations of South Georgia, Dr. Heim remarks that the rocks are not sufficient to prove that the island belongs to the folded mountain system of the Andes and Antarctic Andes. Nevertheless, he adds, the appearance of the folded Mesozoic beds, the presence of the tuffs and basic eruptives, and the characters of the associated plutonic rocks in South Georgia and Grahamland form a striking geological reflection of the Patagonian Cordillera.

Since the visit of the German Antarctic Expedition South Georgia has been further examined owing to the public-spirited generosity of Th. Salvesen, Esq., of Leith, by Mr. D. Ferguson, whose work throws much fresh light on the geology of the island and some doubt on the generally accepted view as to its relations. He found in the slates and limestones of Stromness Bay a number of fossils, which have, however, been so crushed that their identification is a matter of extreme difficulty. The fossils include some dichotomous stems which may be dismissed as fucoids. The most definite specimens are some vertical sections through what appear to be massive cylindrical tabulate corals. The best specimen is 45 mm. wide and 70 mm. long; it has thick walls, no septa, and is crossed by thirty tabulæ in a length of 60 mm. The certain generic determination of the fossil is impossible. Its shape was obviously cylindrical; it is above the average size of simple corals; its walls are thick; it has no septa extending far into the interior, but there are traces of septal structure in the wall; and it has no internal vesicular tissue, but many strong tabulæ. This combination of characters is also met with in the coral *Omphyma*. If the fossil be a coral, it

[1] F. Heim, "Geologische Beobachtungen über Süd-Georgien": Zeit. Ges. Erdk. Berlin, 1912, No. 6, pp. 451–6.

would belong to that or some allied genus. Dr. Hinde has kindly examined the specimen, and says that unless it be a coral it is very difficult to say what it can be.

Another group of specimens appeared at first sight the most hopeful of determination. They are cæspitose organisms, of which one tuft is 90 by 100 mm. in diameter; the branches are, on an average, from 3 to 4 mm. in diameter, and they subdivide dichotomously. A section from one specimen shows broken tubuli, which resemble those of monticuliporoids, and the fossil from which this section was cut has a habit similar to that of several genera of Upper Ordovician and Silurian monticuliporoids.

Another series of specimens consist of long unbranched stems, and as their structure seemed to resemble that of sponges they were sent to Dr. G. J. Hinde. He kindly examined them, but declined to accept them as sponges.

A few of the South Georgia specimens were sent to Dr. R. S. Bassler, who kindly examined them and showed them to his colleagues in the National Museum, Washington. He tells me that the opinion there formed is in favour of the specimens being either sponges or fucoids. Dr. Bassler remarks that "one of our Ordovician genera, *Camarocladia*, shows a structure something like these specimens, and for a guess I would say they are nearest this genus. Mr. Ulrich and I agree that they are not Bryozoa, because it is our experience that no matter how great the crushing, specimens preserved as these are show some of the original structure". He agrees that the age of these fossils is probably later than Cambrian and earlier than Devonian. This conclusion is also supported by a small fragment, which, if found in a graptolitic bed, would be regarded as a piece of a monoprionid graptolite. The specimen has been examined by Miss Macphee, who thinks it is probably a fragment of a graptolite; and this opinion is shared by several members of the geological school of this University who have had experience in collecting graptolites in our Southern Uplands. We, however, feel that this fragment is too small for its identification as graptolitic to be anything more than a probability.

The general evidence, then, of this collection is in favour of the calcareous clay-slates of Mr. Ferguson's Lower Cumberland Bay Series, on the north-eastern coast of South Georgia, being either Silurian or Ordovician, though owing to the imperfect preservation of the fossils this opinion is necessarily doubtful. According to Mr. Ferguson the fossiliferous beds rest unconformably on the Cape George Harbour Series, which would be pre-Ordovician or possibly Ordovician. Mr. Tyrrell's description of these rocks shows, however, that they could not have differed greatly in original composition from those of the Cumberland Bay Series.

Above the horizon from which Mr. Ferguson obtained his fossils is a thick succession of sediments, which he regards as one continuous series. Interstratified with these rocks are abundant tuffs, and a diabase sill is intrusive in the Lower Cumberland Bay Series. The igneous centre discovered by Dr. Heim further to the south-east may be the source of the volcanic debris in the Cumberland Bay Series.

During a study of the microscopic structure of these rocks Mr. Tyrrell found a series of Radiolaria in various specimens, and they are especially well preserved in one band. Some sections have been kindly examined by Dr. Hinde. He reports: "The following genera appear to be represented: *Cenosphæra*, *Cenellipsis*, *Amphibrachium*, *Archicapsa*, *Dicolocapsa*, *Tricolocapsa*, *Dictyomitra*, and *Stichocapsa*. The three first-mentioned genera would be included in Haeckel's Spumellaria, the other six in his Legion Nasselaria. At present I should consider from the general character of the forms in these two sections that they are post-Palæozoic and pre-Tertiary in age, and they might come in between the Triassic and the Cretaceous. But this view might be modified by further knowledge from the contents of fresh sections."

Hence the Middle Cumberland Bay Series includes rocks which, according to the Cephalopod, are probably Cretaceous; according to the Radiolaria are probably Jurassic; and according to Mr. Ferguson's fossils the lower division is probably Silurian.

The available evidence, therefore, regarding the geology of South Georgia unfortunately leaves the relations of the island inconclusive. Mr. Ferguson is strongly of the opinion that his three divisions of the Cumberland Bay Series form one continuous succession, and his excellent photographs support that conclusion. Moreover, the similarity between the materials of the three divisions show that they were laid down under similar conditions. Each division, as shown by Mr. Tyrrell's description of the rocks, includes bands of tuff and layers containing Radiolaria, and all these divisions are cleaved, though the rocks of the lower division are much more sheared and altered than those in the two upper divisions. The whole of the Cumberland Bay Series appears to have been formed off the shores of a volcanic land, which included some sedimentary rocks, the debris of which formed the grits and greywackes of the lower division.

The palæontological evidence, however, suggests that the lower division is Ordovician or Silurian, and that the middle and upper divisions are Mesozoic. That at least a part of the series is Palæozoic is supported by the fact that, according to Mr. Ferguson, both he and Dr. Pirie regard the rocks as strikingly similar, lithologically, to the graptolite-bearing rocks of the South Orkneys. We are therefore left with two alternative explanations. South Georgia may consist mainly of Mesozoic marine sediments, interstratified, as in the Andes, with contemporary volcanic material, and the rocks may have been folded and faulted by movements belonging to the Andean System. On the other hand, if the presence of marine Ordovician or Silurian sediments and the absence of Kainozoic volcanic activity be confirmed, these facts would be less favourable to the view that the island is part of the Andean Mountain System. The island might be a folded fragment of the Flabellites Land of Professor Schwarz, and the loop of the Andes which connected Grahamland with Southern Patagonia would have passed to the west of South Georgia. We must await better fossils and further evidence as to the igneous rocks before choosing definitely between these hypotheses.

III.—The Relationship of Isostasy, Earthquakes, and Vulcanicity to the Earth's Infra-Plutonic Shell.

By L. Leigh Fermor, D.Sc., A.R.S.M., F.G.S.,
Geological Survey of India.

THE recent discussion on the origin of the Himalaya, initiated by Colonel S. G. Burrard in his paper "On the Origin of the Himalaya Mountains",[1] has centred in the theories of isostasy and mountain compensation advocated by the Rev. O. Fisher and Mr. J. F. Hayford.

In his latest contribution to the subject Colonel Burrard[2] states very clearly the problem of isostasy now requiring solution—

> "Continents and mountains have been found to be compensated by underlying deficiencies of density; how has this condition resembling hydrostatic equilibrium arisen upon a solid globe of rock?"

In a recent paper[3] I have advanced reasons for believing in the existence in the earth's crust at a certain depth, at present unknown, of a highly garnetiferous shell of rock, for which the name *infra-plutonic zone* or *shell* is suggested. This zone is situated at such a depth that pressure becomes a dominant factor in mineral transformations, the accompanying high temperature ensuring a sufficient degree of molecular mobility. It is suggested that under the influence of these high pressures (and temperatures) reactions will ensue between the various ferromagnesian silicates—micas, amphiboles, pyroxenes, olivines—and anorthite felspar, with the formation of garnet as a characteristic mineral: the reason assigned is that a reduction of volume accompanied by an absorption of heat is thereby effected, it being accepted that the garnet-forming reactions are endothermic.

If one can accept the philosophical necessity for the existence of this infra-plutonic shell, then some theory of *isostasy* seems logically to follow, with the garnetiferous plastic-solid shell as the cushion upon which the isostatic adjustments of the earth's crust have their foundation.

For if by tectonic movement the superincumbent pressure be relieved over any section of the infra-plutonic shell, the prevailing high temperature will cause the infra-plutonic rock to liquefy, with considerable increase of volume and evolution of heat (the resultant melt corresponding presumably no longer to the infra-plutonic phase, but to the silicates into which it will freeze on solidification under reduced pressure). This highly heated magma is now available for intrusion to higher levels in the crust according to the direction of application of dynamic pressure, and it may either solidify at higher levels under reduced pressures as a plutonic rock, or it may reach the earth's surface as a lava, either directly, without chemical modification, but, probably, more often only after suffering some degree of magmatic differentiation in intermediate reservoirs.

[1] Survey of India, Professional Paper No. 12, 1912.
[2] Geol. Mag., September, 1913, pp. 385–8.
[3] "Preliminary Note on Garnet as a Geological Barometer and on an Infra-Plutonic Zone in the Earth's Crust": Records Geol. Surv. Ind., xliii, pp. 41–7, 1913.

From the isostatic point of view the chief features to emphasize are: (1) that the infra-plutonic shell is everywhere a potential magma-reservoir; (2) that with relief of pressure any given portion may, with expansion of volume and release of heat, become an actual magma-reservoir; (3) that the molten magma approximates in composition and therefore probably in volume much more closely to that of its plutonic (i.e. non-garnetiferous) phase than to that of its infra-plutonic (i.e. garnetiferous) phase.

It will now be seen that any degree of isostatic compensation of a given column of the earth's crust can be effected by the passage of the requisite amount of rock from the dense, infra-plutonic, garnetiferous phase to the less dense, plutonic, non-garnetiferous phase, or vice versa.

Although this hypothetical garnetiferous zone would maintain a perfect hydrostatic balance in the earth's crust if the superincumbent columns of rock were free to respond as a whole to every small application of stress, it must be remembered that the upper layers of the crust are under lower temperatures and pressures, and are elastic rather than plastic solids, responding to applied stresses by bending and fracturing instead of by flowing. They are consequently able to accumulate a certain amount of strain, this ability accounting at least in part for the imperfect isostatic compensation of parts of the earth's crust.

Earthquakes are now generally regarded as the results of attempts on the part of the earth's crust to release these strains by fracturing, and it is suggested that every large earthquake is accompanied by the passage of a proportional amount of garnetiferous into non-garnetiferous rock, or vice versa, according to the direction of movement of the overlying rock. Although this interpretation of earthquakes follows logically from the foregoing explanation of isostasy, yet it was first suggested to me by Mr. R. D. Oldham in a private communication. He writes—

"I had been searching for some satisfactory explanation of big earthquakes, which seem to require a fairly extensive though still local and fairly rapid expansion in the deeper layers of the earth's crust, and had come across none which had any relation to the actual composition of the earth. The passage from the infra-plutonic to the plutonic mode would give just such an effect as I want."

Judging from Mr. Oldham's letter, the change of phase accompanying earthquakes is predominantly one from garnetiferous to non-garnetiferous (solid or liquid).

Perhaps before closing this note I may permit myself to indicate the bearing of my hypothesis on *vulcanicity*. The present general opinion on the cause of vulcanicity is well expressed by Dr. Harker in the following passage (*Natural History of Igneous Rocks*, p. 37):—

"It appears, then, that we must seek the immediate cause of igneous action, not in the generation of heat, but chiefly in *relief of pressure* in certain deep-seated parts of the crust where solid and molten rock are approximately in thermal equilibrium."

According to this idea the temperature of a molten lava is an expression of the algebraic sum of three factors, namely: (1) the temperature of its solid phase before release of pressure; (2) the latent

heat of fusion; (3) the heat changes incidental to the solution of one constituent of the magma in another. But these three factors do not seem to give an adequate explanation of the total heat of some lavas. Basaltic lavas poured out during fissure eruptions, such as those of the Deccan of India, have often flowed superficially many miles from their parent fissures before solidifying; furthermore, before reaching the surface these lavas have doubtless traversed great thicknesses of relatively cool rock continuously abstracting heat. It is difficult to understand how the initial temperature of the magma, based on the three factors referred to in the previous paragraph, could have been high enough to ensure the great fluidity of the basaltic lavas at the surface, in view of the constant losses of heat suffered *en route*; consequently, it seems likely that there is a fourth factor in the heat equation.

The probable exothermic character of the reaction by which the garnetiferous phase of a rock passes to its non-garnetiferous phase (or to its liquid phase) suggests this fourth factor, and enables us to understand how magmas formed by the melting of solid rock due to release of pressure may often possess a surplus quantity of heat due to change of chemical phase above the quantity of heat due to change of physical phase.

I have discussed these questions on the hypothesis that the infra-plutonic shell is characterized by one particular mineral, garnet, that is formed endothermically under high pressure. Further investigation may show the probability of other condensed minerals playing an important part in the same sense as garnet; and, in conversation, Professor R. D. Daly has suggested to me that it would be better not to base my arguments entirely on garnet, but rather on *the general principle of the existence of an infra-plutonic shell composed of dense minerals tending to pass exothermically into less dense minerals on release of pressure.*

Finally, it must be stated that the foregoing notes are intended to form merely a rough statement of the bearing of this hypothetical infra-plutonic zone on the interpretation of the problems of isostasy, earthquakes, and vulcanicity. It is recognized that temperature and water factors must modify the reactions, at least to a certain extent; but it is believed that at the depths under consideration pressure is the compelling factor in chemical changes, the chief function of high temperatures and water (when present) being the ensurance of molecular mobility.

IV.—Cordierite in Granite from Dartmoor.

By F. P. Mennell, F.G.S.

THE presence of cordierite does not seem to have been often recorded from the granite of Dartmoor, in spite of the abundance of that mineral amongst the contact-altered sediments surrounding the igneous mass. The recently published Survey memoirs on Dartmoor and Ivybridge cover nearly the whole area of the granite, and I can only find references to two specimens in which cordierite, or rather pinite pseudomorphs representing that mineral, have been

detected microscopically.[1] Within the limits of the granite proper the mineral does not appear to have been observed at all in an unaltered condition, at least so I infer from the absence of any record of it in the above-mentioned memoirs, as I must confess to a somewhat scanty knowledge of West of England geological literature. Having recently done a certain amount of geologising along the northern margin of Dartmoor, which has not been investigated by the Survey since the introduction of modern petrographical methods, and having obtained some rather interesting results, of which I hope to publish shortly a detailed account, I was glad to take advantage of an opportunity presented by a visit to the South of Devon to make some comparisons with the contact and other phenomena described by the Survey.

One of the excursions made with this object was to Ivybridge, where the chiastolite slate is well known to geologists and where the other andalusite-bearing rocks have been well described by Mr. Barrow. Going up from the railway station alongside the Erme valley, over the track which leads past a quarry where the chiastolite slate is well exposed, one soon comes upon the granite, of which a second small quarry affords an excellent section, close to its margin. Nearest the contact the rock is even-grained and rather discoloured by alteration. Further away, however, a fresh, grey, biotite granite with large white pseudo-porphyritic felspar crystals is seen. Through this are sparingly distributed idiomorphic six-sided or somewhat rounded stumpy prisms of a dark-green mineral, often $\frac{1}{4}$ to $\frac{1}{2}$ in. in length. The habit and general appearance of the mineral are quite sufficient for its identification as cordierite, though the exceptionally well-marked basal parting gives some of the specimens a rather unfamiliar aspect. Many of the crystals are semi-transparent and glassy-looking, and even the more altered of those which are conspicuous in hand specimens are, for the most part, colourless and transparent in thin section except round their margins. They show, however, here and there, some regularly distributed brownish enclosures like those seen in diallage. Faint yellow pleochroic halos are also occasionally seen, as well as some yellowish stains which are not pleochroic. The smaller crystals, that is to say, those which are only a millimetre or so across, are altered throughout to greenish matted 'pinite' aggregates. A specimen which I secured, but have not sliced, contains a little rounded patch about $\frac{1}{3}$ in. in diameter, consisting of fresh cordierite and a reddish mineral which I take to be andalusite. The latter is very common in the adjacent contact rocks, and I have found it to be abundant along the northern margin of Dartmoor in certain offshoots of the granite, but it is curious that this fine example of a granite containing fresh cordierite in conspicuous crystals should be found where that mineral does not seem to have been detected among the metamorphosed sediments.[2] It may be surmised that the absorbed material, which has recrystallised in part

[1] Dartmoor memoir, p. 38. Mr. L. J. Spencer kindly ascertained for me that there is no British specimen of unaltered cordierite in the National Mineral Collection.

[2] The word cordierite does not appear in the index to the Ivybridge memoir.

as cordierite, came from a higher horizon than is now left exposed. It may perhaps be noted that tourmaline is comparatively rare in the rock, although the sediments at the immediate margin are much tourmalinised and have been so altered in the process that all the original andalusite has disappeared. Its rarity may well have something to do with the freshness of the cordierite, as I had already been led by a study of the Cape Town granite to attribute to processes connected with tourmalinisation the conversion of that mineral into aggregates of 'pinite'.

V.—Ice-flows in the Trent Basin.

By R. M. Deeley, M. Inst. C. E., F.G.S.

IN 1866 I communicated a paper to the Geological Society of London on the Pleistocene Succession in the Trent Basin. The boulder-clays and outwash deposits of this district are of two distinct kinds, the one containing rocks from the west and north-west, and the other boulders etc., from the east or north-east of the district. In all cases, except where they have been ploughed up and re-arranged by the ice itself, the drifts containing westerly rocks only are the lowest, and the drifts with easterly rocks have been spread over them. We thus have two distinct ice-flows to deal with.

I contented myself in 1886 with describing the nature of the deposits, the conditions under which they were formed, their succession and the ice-flows they indicate; no attempt being made to explain how the variations in the direction of the ice-flows arose. For some years doubts were felt by many as to the constancy of the succession described, it being considered that the Trent Valley was an area in which the easterly ice-flow met the westerly flow, and that the deposits merely indicated that in this area the ice-flow from the west overpowered the flow from the east and vice versa. The mapping of the area, however, by the officers of the Geological Survey confirmed my general conclusions, that the westerly drifts were the first to be laid down and that the easterly drifts were subsequently spread over them.

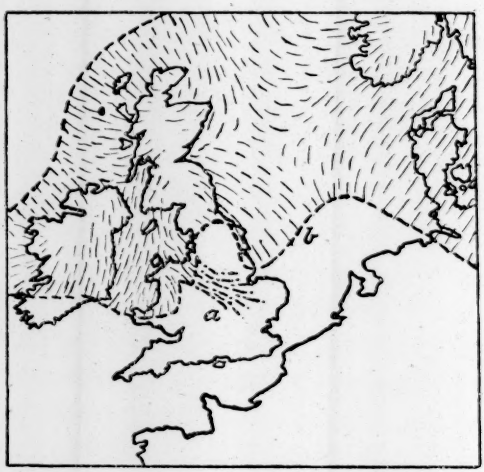
Harmer suggested that the westerly ice passed down the Trent Valley in the first instance, and that it was at a later date thrust back by the great ice-sheet which crossed the German Ocean from Scandinavia. Such an explanation at first sight appears very feasible; but the nature of the deposits, and their arrangement with regard to each other, does not appear to me to admit of such an explanation; for had the area been entirely covered by ice, the direction of the flow of which varied, boulder-clays and mixed gravels only would have been formed; whereas each kind of boulder-clay is accompanied by its own kind of outwash gravels and sands.

Since 1886 our knowledge of the nature of the deposits formed by glaciers, and the method of their formation, has been very greatly increased. Alaska, Greenland, Spitzbergen, and the Antarctic area have all been more or less explored, with the result that glacial problems have had a good deal of light thrown upon them. But even

now, when we come to deal with such an area as that of the Trent Basin or the south-eastern counties of England, there are great difficulties to be faced. In the present paper a *tentative* attempt will be made to show how, through the peculiar ice movements, the arrangement of the deposits indicated came about in this area.

In the Trent Basin there is a series of boulder-clays, gravels, and sands, which occur in the same order throughout the whole of the area, and in many cases all the members may be found within a few miles of each other. Perhaps in no one section is the whole succession shown; but in very many instances several of them may be seen superimposed the one upon the other.

The succession, commencing with the most modern, is as follows:—



Chalky Gravel.—Sand and gravel, with flints, rolled chalk, etc.

Chalky Boulder-clay.—Tough bluish boulder-clay, containing chalk, flints, and other easterly rocks: some derived from older boulder-clays, sands, or gravels.

Melton Sand.—Thick sand beds, with chalk and flint.

Middle Pennine Boulder-clay.—A tough boulder-clay containing well-striated rocks from the west and north-west only.

Quartzose Sand.—Clean false-bedded sand and gravel up to 20 feet thick, quite free from flints.

Early Pennine Boulder-clay.—Reddish, silty, tough boulder-clay, with striated westerly and north-westerly erratics.

Some of the well-stratified sands and gravels I now consider to be distinct from the Quartzose Sand. Those at Kirk Ireton, Spondon, and Grantham are cases in point. They are most likely outwash gravels of the Middle Pennine Boulder-clay. All the sands and gravels are quite free from contemporaneous molluscan remains. Even the clean, false-bedded sands are free from all such signs of life. In this respect they resemble the outwash deposits of modern glaciers and the sands and gravels of glacier-dammed lakes. As has been already stated, their most marked peculiarity is that they

consist of two distinct kinds of boulder-clay and gravel, the upper series being derived from the east and the lower from the west and north-west. This great disparity in the nature of their rock contents induced me in 1896 to regard them as belonging to two distinct epochs of glaciation. I am now, however, of the opinion that they all belong to one great period of ice advance and retreat, which was probably marked by considerable but minor oscillations of the ice-front; for although the area might appear to be anything but a marginal region of the ice-flow it really occupies such a position.

As far as England is concerned, the distribution of the boulder-clay and moraines seems to show that the ice-margins paused, on two separate occasions, along different lines. These two lines are regarded by many, and for good reasons, to be the margins of the maximum extension of the ice-sheets of two different periods. Whether this be the case or not, these two ice-margins throw very considerable light upon the problem with which we have to deal.

In the Figure is shown the probable ice-margin in the British Isles and the North Sea during the time the Purple Boulder-clay was formed. The British ice is then considered to have filled the Irish Sea Basin and mounted the watershed between the Trent Valley and the Cheshire Plain. If there were several periods of ice advance they probably all went through this stage before reaching a maximum. With increasing cold we may imagine that the Irish Sea ice at *a* (see Figure) passed into and down the Trent Valley before the Scandinavian ice-sheet (*b*) reached it from the other direction. Indeed, the Irish Sea ice may have collected rapidly, being in the track of the moist Atlantic winds, and arrived at its maximum development and formed the Early Pennine Boulder-clay long before the Scandinavian ice-sheet reached the Trent Valley area.

But upon this Early Pennine Boulder-clay there rests the thick bed of false-bedded Quartzose Sand. This deposit, there is good reason to suppose, was deposited in open water which was flowing from the west. The retreat of the ice-margin to the west again, the Quartzose Sand indicates, may have been due mainly to a slightly warmer interval supervening. We must, however, assume that the water-level in the Trent Basin was considerably raised, or the fine sand beds would not have been formed. Such a ponding up of the water-level might have been the result of the blocking up of the North Sea by the Scandinavian ice-sheet. Whether the Straits of Dover then existed and the water-level was raised over a large area of the south-east of England, or whether the ice merely ponded up the water in the Trent Valley, is not certain. The creation of a glacial lake in the Trent Valley would of itself tend to melt off the western ice-lobe, issuing from the basin of the Irish Sea, and cause it to retreat, in addition to the melting produced by a temporary amelioration of the climate. The latter was probably the most effective agent of change.

At the end of the Quartzose Sand stage the climate became colder and the western glacier-lobe readvanced. A sand-pit in the Quartzose Sand at Aylestone, south of Leicester, showed a thick bed of fine current-bedded sand covered by reddish boulder-clay containing

Charnwood rocks. These had in many cases been clearly dropped on the bottom of the lake by shore-ice from the Charnwood Hills. Indeed, Charnwood rocks are found many miles north of the Charnwood area in places to which glaciers could not apparently have carried them. They were most likely spread abroad during the time of the existence of this glacier-dammed lake.

The return of colder conditions, on the passing away of the short warm period during which the Quartzose Sand was formed, led to the return of the ice from the west, and the Middle Pennine Boulder-clay was spread over the earlier drifts. The ice of this stage went a long way west, at least as far as, or even beyond, Lincoln.

The Middle Pennine Boulder-clay is a very widespread deposit. The ice-sheet in the Irish Sea Basin, in addition to reaching the Trent Basin over the low watershed to the south-east, passed over the high watershed at Dove Holes, near Buxton, flowed down the Wye and Derwent Valleys and joined the main ice-stream near Derby. Boulder-clays of this age have been found near Bakewell, where well-scratched and distant erratics are numerous. Another patch of boulder-clay of this age is to be seen at Crich, resting upon a glaciated limestone surface, the striæ indicating a flow down the valley. Erratic boulders and boulder-clay also occur on the limestone area of the High Peak. The Crich deposit contains many distant erratics, as well as large polished and striated boulders of mountain limestone, etc.

Following the formation of the Middle Pennine Boulder-clay, a rise of temperature would seem to have come about, for the glacier-lobe retreated to the westward. But this amelioration does not seem to have stopped the flow of the ice from Scandinavia. This ice then advanced over the Middle Pennine Boulder-clay and outwash gravels, and laid upon them thick deposits of boulder-clay, silt, gravel, and sand. The sand and gravel occur, apparently, at all horizons in the Chalky Boulder-clay, but is most strikingly developed towards the bottom and top. The lower deposit, the Melton Sand, seems to have been deposited in open water. I never found any evidence favouring the assumption that the easterly and westerly ice ever met. Indeed, the westerly ice would seem to have retreated very rapidly indeed, and led to the formation of a glacier-dammed lake in the south-westerly portion of the Irish Sea, before the Scandinavian ice had reached its maximum extension. It was during the maximum extension and retreat of the Chalky Boulder-clay ice that the Chalky Gravel was formed.

How far to the west the Chalky Clay and its associated deposits extend beyond Burton-on-Trent I do not know. The water from the glacier lake, however, seems to have been in communication with the Irish Sea Basin lake at Rudyard, and to have overflowed into the Severn Valley, probably by the low cut south of Henley in Arden.

It is probable that the time of maximum cold did not coincide with the time of the maximum extension of the ice. Even in the case of our winter and summer, the lowest and highest temperatures do not coincide with the shortest and longest days. The warmest day occurs about a month after the longest day. Similarly, the greatest

extension of the glaciers occurred some time after the time of lowest temperature, and the Scandinavian ice-sheet may have reached its greatest extension when the British ice was melting away.

Britain, being near the edge of the continental shelf, would respond more readily to temperature changes than the Scandinavian ice-sheet to the north-east. It may therefore have happened, as has been suggested above, that the British ice was on the wane long before the Scandinavian ice reached its greatest extension.

Temporary changes of temperature would also tend to affect the margins of the ice-sheet rather than the centre of the area of dispersion. It thus seems to have come about that the maximum extension of different portions of the ice-margin occurred at different times, and that temporary slight ameliorations of climate affected the margins of the ice-sheet supplied by the British mountains more than they did the marginal portions fed by the Scandinavian ice.

If this reading of what took place be correct, we must not regard a map showing the ground which had been covered by the ice-sheet at maximum extension as indicating the actual extent of the ground covered by ice at any one time, for it would appear that when the North Sea ice reached the neighbourhood of London the glaciers from the British mountains were already on the wane.

VI.—Professor Walther's Erosion in the Desert considered.

By W. F. Hume, D.Sc., F.R.S.E., F.G.S.,
Director of the Geological Survey of Egypt.

(*Concluded from the January Number, p. 22.*)

SECTION 15 deals with the very interesting subjects of *desert films* and *crusts*. Two features are very noticeable in many desert limestone rocks, the production of a hard crust on the outside and of a powdery soft interior. The outer hard layer is often of different colour from the internal portion and highly polished. Professor Walther points out that such hardened crusts occur in buildings in Central Europe, where he suggests that during the dressing of the stone the fine powder produced has been so driven into the pores that chemical agencies are no longer as active. I ventured a suggestion for the production of such sub-crystalline surfaces where much exposed to the sand-blast in which action such as the above was vaguely present to my mind, but whatever external physical effect such external activities may have, the more important is undoubtedly the concentration of solutions near the surface under the influence of the solar heat.

Where erosion along cracks has been of long duration the hard layers may alone be left, giving rise to various gnarled and contorted structures in the rocks which are a characteristic feature in desert limestone weathering.

In a brilliant word-picture (p. 142) Professor Walther draws the contrast between a European and a desert landscape. In the first case a broad covering of green gives the fundamental colour tone. In the desert scene, on the contrary, yellows and browns in every shade from delicate golden yellow to the deepest coffee-brown or

umber are dominant, and even where vegetation is present the tints of green pass insensibly into delicate shades of grey. Only at sunset is the stern scene for a short period replaced by the riotous colouring of a brilliant fairy-land, then with the fall of night the pall of a great desolation is spread over the wild and inhospitable waste.

This year as we steamed down the Gulf of Suez, past the granitic hills of Gebel Zeit, there stood by me three earnest geological students on their way to study the intricacies of these desert regions. In front of those rugged ranges were low foothills of dark and forbidden aspect. "And what are those?" asked my companions, as they gazed on their sombre outlines, recalling the outpourings of some destructive volcano. As I replied "Raised coral-reefs" a silence fell, and it was evident that the questioners found it difficult to believe the statement. Later on, at Abu Mingar, one of them was deeply impressed when he found these strangely scoriaceous masses filled with fossils of the most pronounced character, and realized that the blackened surface was but a thin crust on a limestone which had been eroded by sand and chemical agencies.

Professor Walther distinguishes three types of desert films. The first is the *dust film*, due to the fine dust driven with great force against the rocks. This forms a thin covering, giving a yellow tint to many of the snow-white limestones of Egypt, this being a case therefore where the colouring of the stone comes *from without*.

Most striking is the second group of *cataract films*, beautifully displayed in the cataract regions, where a brilliantly polished crust of graphitic appearance spreads over igneous rocks of every shade and type. Taking as his basis the well-known memoir by Lucas (misspelt Lukas in the text) on the "Blackened Rocks" of the Nile Cataracts, he points out that the materials recorded (much manganese dioxide, ferric oxide, lime, silica, magnesia, with traces of potash, sulphuric and phosphoric acids) are such as would occur in the rocks themselves, which are permeated with water at high Nile. The solutions so formed are subsequently evaporated during the low-water period, with deposition of the dissolved substances as a thin surface film.

In Professor Walther's discussion of this subject he has assumed that the crusts are only formed on igneous rocks. This is not, however, the case, for at Ragama, near Kom Ombo, some distance north of Aswan, a white chalky limestone is blackened to a remarkable extent. In this case it seems difficult to imagine that the film is due to evaporation of internal solutions, and the question cannot yet be considered as finally settled.

The third type, the brown *protective film*, is one of the most characteristic features in desert regions. Its formation is frequently capricious. Fossils in rocks often stand out, intensely blackened, from a light-tinted limestone, and siliceous limestones display the darkening better than finer varieties. The crust is purely a surface one, and only a millimetre thick. It often gives a blood-red or yellow streak, indicating iron oxide where the colouring is yellow or grey; hydrated oxides of manganese and iron are dominant. The brown crust marks the beginning of the change, the red one is the same after loss of water, the addition of moisture restoring the yellow

coloration. In manganese films the streak remains grey, whether the rock be moist or dry. The iron and manganese oxides are mutually replaceable. Professor Walther (following Sickenberger) also cites a case from Dakhla where the crust contained 8 per cent of cobalt, this originating from the thermal springs there.

The gradual development of dark protective films is well shown in the biconcentric circular flints (Augensteine) which are well illustrated in figs. 82–5, showing the progressive stages in depth of colour. The causes noted as producing these results are traces of moisture in the rocks and intense heating by the sun, the water contained in the deeper layers being drawn in a capillary manner to the surface. This moisture acts on the salts of iron and manganese, bringing them into solution, these being redeposited on the surface by evaporation. That the dark colouring is frequently observed on fossils when their matrix is far lighter in tint is ascribed to the presence of phosphoric acid, derived originally from the organisms, while in addition silicic acid in the crystalline rocks and phosphoric acid in the limestones are stated to have such an affinity for iron and manganese oxides that at the point of contact chemical action is set up, which retains the oxides, while the chlorides are removed by the wind.

At p. 149 Professor Walther combats the view that the desert films are directly due to rain or dew. Had this been the case, these should become less marked in passing from the Nile Valley into the arid desert, and again reappear in the region of the oases. On the contrary, his experience has been that the brown crusts become less marked as the more rainy districts are approached, and the films are therefore essentially rainless desert structures, due to the evaporation of highly concentrated solutions under the influence of the high temperatures.

While agreeing with the general proposition, I am certainly under the impression that the crusts are more marked in that portion of the desert near the Nile Valley. The oases occupy so small an area in the Sahara that their effect in any case would be almost negligible.

Section 16 deals with Erosion by Water, in which it is mentioned that such streams as the Nile and the Colorado are in reality strangers in the great desert system, the former especially being similar, in all respects, to streams in the humid or pluvial regions, and only differing from them by its long traverse across the desert belt. The essential feature determining erosion by water in the desert is the sudden rain-storm, and the point is emphasized by illustrations taken from the neighbourhood of Helwan, in the Sinai Hills, and the Kharga Oasis. The activity of the rain is short-lived, but intense while it lasts. Years, nay centuries, may elapse, before another storm breaks in the same locality, and in fig. 93, the Ras-el-Kadi (in Kharga Oasis), an illustration is given of such a torrent-conglomerate based on soft clayey strata, which have undergone sand erosion, leaving the torrent-conglomerate as the head of a 'mushroom', of which the stalk is composed of the clays. In desert rain-storms an essential feature is the widespread character of the torrent, to which MacGee has given the term of 'sheet-flood' and Passarge of 'Flächenspülung' (p. 163), the waters not following definite channels, but extending

in broad sheets over the whole surface. As a result, delta-like deposits are produced at the mouths of the valleys, the Cooper Creek delta in Australia, originally described by Eyre, being given as an example of such a feature, which far exceeds in extent the great river deltas of the Nile and the Danube.

Section 17 is devoted to *Deflation*, or the *activity* of *wind* as a *transporting agent* of the light materials formed by erosion or composing the softer rocks. This agency Professor Walther considers to be the most important of those acting in desert regions.

An illustration is given of the beginning of a dust-storm on an Australian farm, but equally good examples are available from the Sudan, very fine photographs having been taken of such phenomena at Khartoum. Dust is carried for hundreds of metres into the air, a sand-storm when viewed from the summit of a hill above its influence being an impressive and awe-inspiring spectacle. Personally I entirely agree with Professor Walther as to the importance of deflation in the Libyan Desert; in the Eastern Desert of Egypt water action is probably as effective a factor.

One of the noticeable effects of sand-laden winds is the formation of hollows (often arranged in network patterns) in the faces of sandstone cliffs or on the sides of granitic outliers. Walther, following Futterer, maintains that it is a mistake to ascribe their genesis to the action of sand blown by wind only; in the majority of instances the cavities have been formed by the effects of insolation on the solutions in the rock, the weathered material due to the action being then carried away by the wind. In this way granitic blocks may be completely eaten through, giving rise to arched cavities. If these processes be continued the rocks are eventually worn down to isolated blocks of remarkable shapes, in which the 'mushroom' form predominates.

Sections 18–20 deal with the character of the desert surface resulting from the sweeping away of all the lighter materials by the wind. A series of illustrations exhibit the character of the great plains in the Western Desert and Ethiopian region due to the removal of the finer particles where limestone and conglomerates are predominant; in the sandstone regions a vast expanse is produced, out of which rise isolated tabular outliers, sometimes protected by a hard ferruginous cap.

In Section 20 Professor Walther establishes five diverse regions as regards the forms produced by denudation and their geological history.

1. The *Serir*, in which strata of sand and flint pebbles or boulders have formerly spread over the surface. From these beds the sand has been removed, leaving a waste of large fragments embedded in the soft material which still remains. This *flint* desert gives rise to gentle undulations in which no conspicuous features are developed, and is characteristically displayed to the west of the Pyramids.

2. The *Hamada* is a region where hard limestone bands alternate with softer bands of marl and clay. The limestone beds form hard surfaces, which, remaining after the removal of the softer strata, give rise to broad and desolate plains extending unbroken in every

direction. Change to a higher limestone stratum is marked by a low step only a few metres in height, leading to another extensive plateau in which the *hamada* character is faithfully reproduced. Professor Walther could have carried his description further, for these surfaces vary according to the nature of the limestone stratum. Sometimes the desert floor is entirely composed of fossil remains, oysters or nummulites, at others of sun-warped sub-crystalline limestone scoured deep and even cut into long hummocks by the wind-borne sand.

3. The third place is given to the Wadis or Dry Desert Valleys, special attention being called by picture and description to their precipitous terminations, often in great amphitheatres. In the formation of these deep ravines, erosion by water and deflation are regarded as both having taken part, the mighty effects of one day of rain-storm being followed by the activities of the wind during long periods of dryness. Here main channel and tributary have little meaning, and valley slope is often difficult to determine, except in the major watercourses of the country. Narrow ledges often separate two branches until some great rainfall sweeps them away. If these sudden torrents are so effective in the dry sun-cracked wilderness, the greater streams, such as the Colorado and the Nile, must be more intensely destructive, and erosion works on a scale to which no parallel exists in more temperate climes.

4. From the valleys, eating backward into the desert plateaux, there is but a short step to the *Outliers*, which, first extending as bold and precipitous projections from the main cliff face (Zungenberge), (see fig. 120, p. 205), finally become separated, forming isolated hills. In this section it is necessary to point out that a factor works of which, if I mistake not, Professor Walther has taken no notice.

In the Lower Eocene series huge masses of limestone rest on clays. The rain falling on the plateau surface percolates through the limestone and forms a water-cushion over the impermeable beds beneath, upon which the heavy superincumbent strata tend to slide. This geological factor is of the highest importance in a wide region of Upper Egypt.

5. Naturally the great depressions of the *Oases* attract special notice, and Professor Walther holds that after weighing all the facts there is only one conclusion possible, viz. that the whole of the mass of material removed from these areas has been carried away by the wind. This seems to me to assign far too important a rôle to deflation, and to ignore the vast amount of marine erosion which must have taken place during the elevation above sea-level of the strata deposited during Eocene and Cretaceous times.

6. The Nubian Sandstone scenery is mentioned in which pyramidal and tabular outliers rise out of vast plains with compact floors composed of the coarse grains not carried away by the wind. In the Geological Survey memoirs it has repeatedly been pointed out that many of the longitudinal valleys in the Eastern Desert of Egypt owe their origin to the presence of the Nubian Sandstone, and result from its easy denudation, while further south this formation is traversed by fine ravines where the transverse valleys draining from the Red Sea Hills cross it on their way to the Nile.

7. In the next section Professor Walther touches very lightly on erosion forms in Sinai and the Arabian Desert, again referring those produced to the influence of water-action and deflation. This section deals with an area so complex and so varied that it might itself without great difficulty be raised to the rank of a volume; but to understand the origin of the stupendous precipices of the Red Sea Hills and the Red Sea depression, the varied features due to dyke-ridges, and the wearing of soft veins of basic rock, or the spreading of gravel plain and ancient coral-reef, requires a clear conception of the earth-movements which have made this remarkable region what it is. Only as the result of the giant earth-creep by which the underlying granitic masses have risen high above the depression of the Gulf of Suez, and the breaking up of a mighty anticline, have we the basis on which rain-storm and deflation, chemical change and sand-scouring are able to work. Marine erosion and tectonic changes of the first magnitude have produced the surface features which have acquired the present desert characteristics by processes so ably described in the volume under consideration.

REVIEWS.

I.—The Life of the Mollusca. By B. B. Woodward, F.L.S., of the British Museum (Natural History), Past President of the Malacological Society of London. 8vo; pp. xii and 158, with 32 plates and a map. London: Methuen & Co., Ltd., 1914. Price 6*s*.

WHEN I was but a youthful aspirant in science I received from Dr. S. P. Woodward a present, in three parts, of his *Manual of the Mollusca, a Treatise on Recent and Fossil Shells*[1] (1851–6). When bound it was only $7\frac{1}{4} \times 4\frac{1}{2}$ inches in size, with 530 pages, 25 plates, and 272 text-figures. The mass of matter squeezed into it was enormous—much more so than the publisher bargained for! I thought it the most wonderful book I possessed, next to Darwin's *Voyage of the "Beagle"*.

That this little work should have held its place as a scientific text-book for sixty years seems almost past belief, and speaks volumes for the great mass of valuable biological facts contained in its small and closely printed pages. Numerous other works on malacology have since appeared, of greater or less importance, by Lovell Reeve, Forbes & Hanley, Henry and Arthur Adams, J. Gwyn Jeffreys, G. B. Sowerby, and lastly by Dr. Paul Pelseneer (author of one of Sir Ray Lankester's Zoological Treatises, part v, 1906), etc., proving that a large section of the public still pursues the study of the Mollusca beyond those perennial lovers of oysters who date back even to our prehistoric ancestors.

[1] It formed one of "Weale's Elementary Series" (afterwards transferred to Virtue & Co.), and of which between 1851 and 1880 upwards of 11,000 copies were sold. In 1880 a fourth edition, price 7*s*. 6*d*. (edited by Ralph Tate), was published by Crosby Lockwood & Co. (its last owners), in which several fossil genera of Mollusca were added in an appendix and the Tunicata removed, but the Brachiopoda retained!

In France Fischer's *Manuel de Conchyliologie* (Recent and Fossil), in eleven fascicules (from 1880 to 1887), with 1,369 pages and 1,139 text-figures, embraces all Woodward's original work, besides very much additional new matter. Chenu's large *Manuel de Conchyliologie* is more valuable for its numerous and beautiful illustrations (many in colour) than for its text.

The establishment of the Malacological Society of London in 1893, now in its twenty-first year, with a published journal of ten volumes, speaks highly for the advance in the scientific study of the Mollusca during the past half-century all over the world.

In days of long ago our neighbours the Dutch were not only the earliest voyagers, they also took the lead in collecting and purchasing rare and valuable shells; but they knew little or nothing about the animals themselves. They were rather like the lady at the "Zoo" who, seeing a hermit-crab in one of the tanks walking about in a whelk-shell, remarked to her daughter how interesting it was *to know* the little animals that *made* those shells.

Even in the days of Robert Macandrew and Gwyn Jeffreys, to collect shells and remove the animals without injuring the test was rather the be-all and end-all of those early conchologists. Edward Forbes, S. P. Woodward, Huxley, Lankester, Paul Pelseneer, Godwin-Austen, B. B. and Martin F. Woodward, and the modern school of zoologists have shown by their published works and lectures that a classification of the Mollusca, based upon an accurate knowledge of *the shells alone*, would be as satisfactory as a tailor's knowledge of a new client derived from inspecting a suit of his cast-off clothes.

In the present work the author tells us his object is "to give a succinct account of what is known concerning *the life* of that branch of the animal kingdom to which the snail, the oyster, and the cuttle-fish belong—the Mollusca". But it is not an easy matter to express in a few words the general characters by which any group or phylum of the animal kingdom can be distinguished from its neighbours. To illustrate this difficulty we may cite the fact that some fifty years ago the Cirripedia, the Tunicata, the Brachiopoda, and some operculated corals (*Calceola*, *Goniophyllum*, etc.) were included in the Molluscan sub-kingdom. "Externally most molluses possess a 'head', a ventral creeping organ, the 'foot', and a dorsal covering, the 'mantle', which bears and secretes the shell. This shell forms a protection to the more vital organs, and into it the animal can generally withdraw for security from attack. The mantle does not usually reach far beyond the shell-margin when the animal is extended, but in some cases it curls round over the shell (e.g. *Natica*), and even as in the cowry (*Cypræa*) meets on the top. In the more specialized Mollusca there is a tendency to the reduction, even to disappearance, of the shell, and in these there is a corresponding liability for the shell to become more and more enveloped permanently in the mantle as the animal becomes less and less able to use it as a place of retreat" (p. 2).

It is surprising to find how full of interesting matter are the living Mollusca when studied as a whole, not merely as dry shells in a cabinet. Take, for example, chapter vii on the evolution of the Mollusca, and quite a new set of ideas are presented to the student.

Thus one is led to consider where the mollusc began to take up his abode, and it is suggested that the tidal zone was in all probability the cradle of the race. "From the shore-line the various members betook themselves to probably deeper and deeper water on the one hand, but also, though perhaps more tentatively and gradually, to fluviatile and terrestrial conditions on the other." Thus we see the early human infant begins his marine efforts by 'paddling', and it is long before he attempts deeper water or, like the Argonauts of old, risks a pelagic adventure far from land. From the earliest times soft-bodied (molluscous) animals have doubtless been attractive to their fellows as well as to the early nomads who lived upon the waifs and strays which the waves cast up upon the shore. The shell of all types, univalve, bivalve, and multivalve, were a necessity to these early molluscs. "Primarily among the inhabitants of a rough foreshore the massive strength of the shell is noticeable, the object being of course to withstand the battering action of the waves and hard substances, like stones, cast up by them" (p. 103).

The limpets with their tent-shaped shells afford an example of an excellent protective form of covering for a surf-dweller on rocks. The *Trochus*, Turbos, and Neritas among spiral forms have usually stout shells and often also a shelly operculum or door to their houses. Such forms as *Littorina*, *Purpura*, *Nassa*, *Pterocera*, *Turbinella*, and *Strombus* require much sea hammering to break their shells. In deeper water, however, where no surf breaks, the thick heavy shell of the Gastropods ceases to be of service, and the inhabitants adopt a much thinner and lighter covering (p. 104).

Among the bivalves (Pelecypoda) also the shore frequenters often have very stout and convex shells, like the Giant Clam (*Tridacna*) and the *Hippopus*, and can withstand the full beat of the ocean waves; so too could the Rudistes among the fossil reef-building molluscs. But "most of the Bivalves, as a matter of fact, do not live in exposed situations, but burrow more or less deeply into soft sand or silt". Those that do not penetrate to any depth below the surface, nor live in deep water beyond the reach of ground-swells, such as the Cockle, *Cardium*, the Veneridæ, etc., are often disturbed by storms and thrown up alive upon the beach. Their activity, however, frequently enables them to get back (by walking with their foot) into their briny home, where they quickly bury themselves once more in the sand.

All sections of the group except the bivalves have a distinctive feeding organ, the 'radula'. It occupies the same position in the mouth as does the tongue in the higher animals, and consists of a series of recurved teeth, formed of dense chitine, attached in transverse rows to a membrane of the same substance. "The number of teeth in each transverse row varies from one in certain sea-slugs to upwards of two or three hundred as in the 'top shells' and their allies (*Trochus*, *Haliotis*, etc.)" (p. 11). The whelk has about 250, a big limpet 2,000, the periwinkle 3,500, the common garden snail 15,000, and the big grey slug 26,800. As in the higher animals, "the form of the teeth are some index to the diet of the animals, the purely herbivorous having short broad-pointed teeth, the carnivorous

sharp-pointed teeth, which in those feeding on *living animals* are barbed to retain their prey, while in the Cones the teeth are not only barbed but perforated and connected with poison glands."

"In habit the Mollusca are far from active, only some of the cuttle-fishes being capable of spasmodic rapid motion, so much so that the term 'sluggish', borrowed from them, best describes them." (p. 13.)

Let us now turn to the geological history of the Mollusca. In chapter iii Mr. B. B. Woodward tells us these animals made their appearance very early in the world's history, the more generalized forms preceding the more specialized. In the oldest fossiliferous beds of the Lower Cambrian only a few representatives have been found. These consist of some limpet-like shells (*Scenella, Stenotheca, Platyceras*); also a turreted convolute shell (*Raphistoma*), and the remains of two bivalves.

In the Upper Cambrian further examples of the early Rhipidoglossa are found (*Murchisonia, Cyrtolites, Owenella,* and *Straparollina*), as well as one (*Trochonema*) a supposed member of the higher one-gilled section of that sub-order. Already, too, seven species of Cephalopoda had made their appearance, all belonging to the more primitive straight-shelled section of the Nautiloidea. In the succeeding Ordovician epoch Aspidobranch Gastropods predominated (*Cyclonema* and top-shells, Turbinidæ), and the first Chiton appears (*Priscochiton*). The Cephalopoda are represented by sixty-five species of Nautiloidea, mostly straight-shelled, but some curved and a few coiled forms.

Considerable increase in the Mollusca occurs in the Silurian epoch. Members of three families are added to the Gastropods, and of Pelecypods Palæoconchs were most abundant. Two more Chitons appeared and some doubtful Scaphopods. "The Nautiloidea attained their zenith with about 230 species, among which the coiled were almost as abundant as the other shell-forms. From that day the group has steadily diminished in numbers, only five species now existing"—probably not so many.

In the Devonian strata there is a still further increase of the Pelecypoda (Trigoniæ, Pectinidæ, Mytilidæ, and many others). The first freshwater mussel, *Archanodon Jukesii*, appears, closely resembling the modern *Anodonta* (swan mussel) of our ponds and lakes. A true *Dentalium* and representatives of the more primitive Ammonoidea (*Clymenia*) and Goniatites appear in the Devonian epoch. At its close land-snails (*Strophites, Dendropupa,* etc.), allied to the chrysalis shells, have been found in the plant-beds of St. John's, New Brunswick. The Coal-measures of the Carboniferous period have yielded some other interesting air-breathing snails (*Dawsonella,* etc.), the first brackish-water snail (*Ampullaria*), a freshwater snail (*Physa*), and a small land shell (near to *Pyramidula*), a common form to-day. Many examples of freshwater bivalves (Cardiniidæ) were plentiful in the Carboniferous; the oldest Tectibranch (*Cylindrobullina*) has been obtained, and a highly specialized bivalve (*Lithophagus*) that burrows into rock, shell, or coral.

Although at the close of the Palæozoic period many of the older genera of bivalves disappeared, at the opening of the Mesozoic period in the Trias a number of others came in. Among them we find

more species of freshwater mussels (*Unio*), of the thorny oyster (Spondylidæ), and cockles (Cardiidæ). The oldest examples of the ten-armed cuttlefish here made their first appearance.

"The Jurassic strata are rich in molluscan remains, which sometimes form whole masses of rock. The Gastropods attained their acme of development at this period. Further land shells and the earliest freshwater Gastropods (*Planorbis, Valvata,* and *Melania*) have been recorded from the lowest Jurassic beds, but of their exact determination there is some doubt. In the uppermost beds, however, the well-known Purbeck Marble is composed of masses of *Valvata, Vivipara,* etc." (p. 48.)

"Among Bivalves genuine Ark Shells (*Arca*), *Anomia,* and various families of Eulamellibranchs, including the freshwater Cyrenidæ, made their appearance; while if *Corburella* be admitted as a member of the Septibranchia, that order must be added for the first time. The 'pens' and ink-sacs of earlier members of the *Sepia* tribe (*Belotenthis* and *Geoteuthis*) are first found in the Lias, with the remarkable Belemnites whose 'guards', often called 'thunderbolts', are familiar fossils.

"In the succeeding Cretaceous period further development took place. Among the Gastropods there was a decided increase in the higher Pectinibranchs, including representatives of most of the families of Rhachiglossa. Amongst Bivalves two most remarkable aberrant families (Radiolitidæ and Hippuritidæ) were confined exclusively to this period. Externally these look not unlike simple corals with a lid, while internally they display highly peculiar modifications. Numerous other Eulamellibranchs, including some boring forms such as Petricolidæ and Saxicavidæ, as well as the Razor-fish (*Ensis*), arose, with an undoubted representative of the Septibranchs (*Leiopistha*). An Octopus (*Palæoctopus Newboldi*) standing for the highest Cephalopods was revealed for the first time in the Cretaceous of Mount Lebanon, but, on the other hand, the Ammonites and Belemnites died out.

"During the Tertiary epoch the Rhachiglossa and Toxoglossa became the dominant Gastropods, while the Bivalves showed an approximation to present conditions. A great majority of the Lower Tertiary (Eocene and Oligocene) genera still exist, but none of the species. During the succeeding Miocene a few species, which are still in existence, made their appearance, while of the Pliocene species 80 or 90 per cent. are represented in the recent fauna.

"At the close of the Eocene the wide distribution of many types now characteristic of warm, temperate, or tropical waters, began to be restricted, and during the Miocene the faunal boundaries of the Mollusca were mapped out nearly on existing lines. This was more true of the non-marine forms; but not till the Pliocene did each geographical province come to assume its present distinctive features." (p. 50.)

Space does not admit of a more extended notice of this interesting volume, which gives us in a few concise pages an accurate summary of living and extinct Mollusca. There is an excellent index, but we would suggest in the next edition a glossary for the unlearned reader's use. A diagram of a Gastropod and a Pelecypod

shell would be more useful to the reader in the text of the chapter on Classification to show the topography of the shell, although well illustrated on pl. vi and other plates at the end of the volume. The book needs only to be known in order to be appreciated and widely circulated. We commend it to all students of the Mollusca; those who are not will by reading it no doubt become so.

II.—British *Pisidia*.

Catalogue of the British Species of *Pisidium* (Recent and Fossil) in the Collections of the British Museum (Natural History), with notes on those of Western Europe. By B. B. Woodward, F.L.S., etc. 8vo; pp. x, 144, with 30 plates. London: printed by order of the Trustees of the British Museum, 1913. Dulau & Co., Ltd., 37 Soho Square, W. Price 10*s.* 6*d.*

OF all the groups of British freshwater shells the *Pisidia* have hitherto been the most puzzling. No two authorities have been in agreement and no real test for the species had been noted. It must therefore be a great relief to students to find that at last the golden key has been discovered by B. B. Woodward, who in this monograph shows clearly that the various species can be correctly differentiated by their hinge structures.

Pioneer work of this character is not easy. First it had to be shown that hinge characters were constant; then the various species had to be discriminated and identified with forms previously described on shell form alone; and lastly the whole of the available material had to be examined and compared. The result of all this labour is the volume before us, a volume which will be the foundation of all future work, and everyone who has hitherto vainly tried to identify *Pisidia* is now under a deep debt of gratitude to Mr. Woodward. When we mention that nearly one hundred described species are sunk as synonyms the literary labour alone of the author can be appreciated. Seventeen species are dealt with; fifteen of these are British, one is a living Continental, and one an extinct Pleistocene Belgian form. It is noteworthy how the species have existed unchanged in the British Islands for a very long period. One form ranges from the Coralline Crag (Pliocene) of Suffolk to the present day; four living species are known from Norwich Crag (Pliocene) times, and five recent species make their first appearance in the Cromerian (Forest Bed) of West Runton, Norfolk, whilst one species ranges from the Norwich Crag to the Pleistocene of Crayford.

Environment plays a considerable part in the variation of shell form, and the differences between river forms and lake forms are fully dealt with. Non-recognition of this non-significant variation has in the past been the cause of the multiplication of species.

An excellent feature in the volume is the series of typomaps, thus enabling the reader to ascertain at a glance the exact range of any species on these Islands. The plates are perhaps a little lacking in clearness of definition, and as the original photos were undoubtedly sharp this must be due to the difficulty of printing in numbers. Mr. F. W. Reader deserves praise for his share in this difficult work.

There are a few unimportant errors which we have noticed. Thus, on p. 36 "Pleistocene of Uxbridge" is a slip for "Holocene of Uxbridge", and on pp. 43 and 78 Cappagh is in Waterford, not Limerick. The credit for the first discovery of *P. supinum* is here given to Dr. A. C. Johansen in 1901, but it was recorded from Scotland in 1880 by Sandberger.

This volume begins a new era in the publications of the British Museum, since it deals with specimens preserved in the Geological and Zoological Departments, and the old artificial barrier of "fossil and recent" has disappeared, we hope, for ever.

III.—Text-Book of Palæontology. Edited by Charles R. Eastman, Ph.D. Adapted from the German of Karl A. von Zittel. 2nd edition, revised and enlarged. Vol. I. 8vo; pp. xii, 840, with about 1,600 illustrations. London: Macmillan & Co., Ltd., 1913. Price 25*s*. net.

NEARLY fourteen years have gone by since the appearance of the first English edition of von Zittel's Textbook, and in the notice of it in the Geological Magazine for 1900 (p. 232) attention was drawn to the fact that Dr. Eastman, the translator and editor, had enlisted the assistance of a number of specialists in the principal groups of fossil Invertebrata to act as collaborators with him in bringing out the work. This plan proved so successful that it has again been adopted by the editor in the preparation of this new edition, and at the beginning of the volume he has given a list of seventeen coadjutors and of the particular group or groups of fossils which they have respectively treated. By their efforts the editor states that many parts of the work have been entirely rewritten, others have been amended, re-arranged, and enlarged, and the classification in various places has been considerably altered.

It would exceed our limits to comment on these emendations, but we may just note the rectification of a very conspicuous error in the first edition—that of placing some species of the genus *Monticulipora* with the Tabulate Corals and others with the Bryozoa. The true relationship of the supposed corals is to the Bryozoa, and in the present edition they are rightly placed in this class with their allies.

The principal new fossil forms of Invertebrata discovered since 1900 are included in the present volume, and many of them figured. In this connexion may be mentioned the strange new forms of Medusæ, Chætopods, Holothurians, etc., discovered by Dr. C. D. Walcott in the Middle Cambrian rocks of British Columbia.

Another special feature of the work is the bibliography of the respective groups, which is brought down to recent dates; it also includes references to the more important literature of the recent as well as the fossil forms.

No other work in the English language furnishes us with so complete a description of fossil Invertebrata as the present textbook, and it can be heartily recommended to all interested in the study of palæontology.

IV.—Geological Survey of Scotland.

The Geology of the Fannich Mountains and the country around Upper Loch Maree and Strath Broom. By Dr. B. N. Peach, F.R.S., Dr. J. Horne, F.R.S., the late W. Gunn, C. T. Clough, M.A., and E. Greenly; with contributions by L. W. Hinxman, B.A., T. I. Pocock, M.A., and C. B. Crampton, M.B., and Petrological Notes by Dr. J. J. H. Teall, F.R.S. 8vo; pp. viii, 127, with 8 text-illustrations and 6 plates. Edinburgh: printed for His Majesty's Stationery Office, 1913. Price 2*s.* 6*d.*

THE region described is one of mountains and lochs, with a little of the open sea of Gruinard Bay on the north-west. Deer forests occupy most of the land, the only cultivated areas being along the sea-coast, the lower parts of Straths Beg and Broom, and at the mouth of Kinlochewe River. The more familiar tracts are those along Loch Maree, the portion included being about 9 miles in length, with the Loch Maree Hotel at Talladale and Letterewe on the opposite coast to the E.N.E.

The geological features are clearly shown on the colour-printed map, Sheet 92 (price 2*s.* 6*d.* net). On the west are large tracts of Lewisian Gneiss and Torridon Sandstone, overlain towards the east by unconformable Cambrian rocks. It is pointed out that "the present outlines of the Lewisian Gneiss are, to a considerable extent, a renewal of the pre-Torridonian land surface, which can be shown to have been one of high relief". Thus the Torridonian mountain of Slioch, which attains an elevation of 3,217 feet, comprises nearly horizontal beds of sandstone, which "are seen to envelop three prominent hills of Lewisian Gneiss—one over 2,000 feet in height—with intervening valleys". Some parts of the area may be a restoration of the pre-Triassic land-surface. Rocks of Triassic and Liassic age occur over a small tract on the borders of Gruinard Bay. As at Applecross, they are faulted against the Torridon Sandstone, and the local downthrow is estimated at about 1,000 feet. From Little Loch Broom southwards the Torridon Sandstone forms a fine series of terraced escarpments with corries, as at An Teallach (shown on plate vi), where there are five peaks more than 3,000 feet in altitude. Cambrian quartzites form a prominent escarpment along the eastern exposed area of Torridon Sandstone, and then the ground is greatly disturbed by thrusts and disruptions; a belt of complication due to post-Cambrian movements crossing the area from Loch Broom on the north to the head of Loch Maree and beyond on the south.

The eastern half of the area bordering this region of great disturbance is formed mainly of the Eastern Schists or Moine Series. It "forms part of the Highland plateau, running along the main watershed of the country, which has been deeply trenched by river systems developed since Eocene times". Here is found "some of the wildest scenery in Central Ross-shire". Flaggy siliceous schists and massive muscovite-biotite-gneiss form lofty escarpments and precipitous corries, as exhibited in Fannich Forest (plates i, iv, and v). The Fannich Mountains, which rise to the north of Loch Fannich, include eleven

peaks more than 3,000 feet in height, while Beinn Dearg to the north-east rises to 3,547 feet.

Particular accounts are given of all these formations, their subdivisions, and of the various intrusive rocks. The fossils of the Cambrian and Lias are duly noted, those of the latter belonging to the Lower Lias. There are interesting descriptions of the glacial phenomena and of the successive phases of the glaciation; and much attention is devoted to the physical features, to the rivers, and to the modification of former drainage systems, especially during the Glacial Period. The influence is pointed out of faults and great displacements on the trend of the lochs and of some of the ravines, and it is remarked that "Of the larger lakes in the area under consideration, some occupy rock-basins and some are due to the irregular distribution of the glacial deposits".

Raised Beaches, Alluvium, Peat, and Blown Sand are noticed, and in a final chapter on Economic Geology an account is given of the iron-smelting formerly carried on along the shores of Loch Maree and the neighbourhood. The only local ore is that of bog-iron, but in later times ores not found in the district were imported. Limestones (Lewisian, Cambrian, and Lias) have been quarried for lime-burning, etc., and various rocks have been used for building purposes and road-metal. Metalliferous veins are rare, and apparently of no importance: they include ores of lead and copper, and traces of gold. Notes on plantations and on the rainfall are included, and there is a useful bibliography.

V.—Contributions to the Geology of the Nordingrå Region. By José M. Sobral. 8vo; pp. 117, with 12 plates, 1 map, and 1 figure in the text. Upsala: Almqvist & Wiksells, 1913.

THE district included by the author under the title of the Nordingrå Region is situated on the east coast of Sweden, extending from Hernön on the south to Mälmon on the north. Inland, and to the north and south of the district, is a large area of Archæan rocks, but the greater part of the region is occupied by a group of igneous rocks—granites, monzonites, gabbros, and anorthosites. These rocks are overlain by arkose and quartzitic sandstones, belonging to the Jotnian formation of Fenno-Scandia, which are themselves intruded and covered by diabase of pre-Cambrian age. The granites and gabbros are clearly pre-Jotnian, and are believed to be post-Jatulian in age. The field relations of the rocks of the various districts are described in detail, and special attention is devoted to the petrography and petrology of the igneous rocks.

On the east of Ramstäfjarden there is a narrow outcrop of igneous rocks, including pyroxene- and biotite-granites, apparently forming a group distinct from the main granite masses of Nordingrå which are largely hornblende-granites. In the Sub-Jotnian igneous rocks of the mainland the order of solidification appears to have been anorthosite, gabbro, granite. There is interesting evidence of assimilation at the contacts of the granite both with the anorthosites and gabbros and with the Archæan leptites. Monzonitic rocks occur in

this area, but the discussion of their relations to the gabbros and granites is reserved for a future publication, which will contain analyses. One development of anorthosite in Nordingrå is remarkable for the abundance of apatite which it contains.

A very striking feature of the petrographical work is the care with which the optical constants of many of the minerals have been determined. The most interesting result of this work is the proof of the occurrence of *fayalite* in many granitic and monzonitic rocks of the region. This mineral appears to occur in several of the typical granites, but it is noticeable that it becomes most prominent in those rocks which are regarded as products of assimilation of gabbro or anorthosite by the granites. The significance of its occurrence cannot be discussed until the rocks have been analysed.

In the two islands of Ulfön there is a large development of granite intruded by diabase with associated acid and basic dykes. The acid dykes are in part contemporaneous with and in part younger than the diabase: they consist of albitites and albite-pegmatites. One of these has been made the type of a new rock name, Värnsingite: it is a coarse-grained rock consisting mainly of albite with some augite, magnetite, and titanite, and is regarded as a 'diabase-pegmatite'. The basalt dykes are the youngest rocks in the district. They show an abnormal development of plagioclase phenocrysts in a narrow zone at their contact with the diabase or granite. This is attributed to inoculation of the intruding magma, when in the metastable state, by the plagioclase of the country rock.

Monzonitic rocks occur in this region and range from rather acid varieties to rocks allied to kentallenites, but containing olivine rich in iron. From a study of the field relations of these rocks the author is led to the conclusion that they are derived by assimilation of granite by the diabase. If this be the case it forms a very important example of the assimilation of an acid by a more basic rock, and, further, it shows that 'hybrid' rocks are not necessarily of very unusual composition. Pending the publication of more analyses these conclusions will possibly be received with some hesitation. Two analyses of kentallenites are given and one of a fayalite-monzonite. The field relations of these occurrences are not conclusive, and the occurrence of fayalite at once suggests comparison with the monzonitic rocks of the mainland; this point will doubtless be settled by the author in his further publications. At Svartbergsviken is an inclusion-like occurrence of monzonitic rocks, grading from adamellite at the centre, through banatites and monzonites, to a variety of the Ulfö diabase, and here the field evidence of assimilation is more convincing. Two analyses of the 'hybrid' rocks are given, together with analyses of the diabase, but still more analyses are needed to strengthen the case. There appears to be no close connexion between the composition of the rocks of this occurrence and the kentallenites and fayalite-monzonites mentioned above, and in criticizing the conclusions of the author the two groups must be considered apart.

Petrologists will await further contributions on these rocks with great interest, for none can fail to appreciate the real excellence of the present work. W. C. S.

VI.—Canada Department of Mines. Geological Survey. Victoria Memorial Museum. Bulletin No. 1. 8vo; pp. 200, of which 13 are printed as plates. Ottawa, October 23 [i.e. November 21], 1913.

THE papers in this new publication are distributed under the headings Palæontology, Palæobotany (thus showing that by Palæontology is meant Palæozoology), Mineralogy, Natural History (which appears intended to include both recent Botany and recent Zoology), and Anthropology (which from the title of the only paper under this heading appears to include Archæology). The Geological Survey of Canada is thus continuing the traditions of the time when it was known as the Geological and Natural History Survey of Canada. There is no heading Geology, for it is doubtless intended that papers dealing with that subject will continue to be published as heretofore in the direct Reports of the Survey. The majority of the papers in the present number have, however, a geological bearing.

The first paper is a redescription of the type-specimen of *Ottawacrinus typus*, W. R. Billings, by Dr. F. A. Bather, who considers that all the radials of this form are transversely bisected, and finds it difficult to draw any clear distinction between the upper halves of such radioles and the proximal brachials. In the following "Note on *Merocrinus*" Dr. Bather applies this view to that genus also. Mr. L. M. Lambe records the occurrence of Helodont teeth in beds believed to be of Upper Devonian age in Alberta. Dr. P. E. Raymond publishes "Notes on *Cyclocystoides*", in which he suggests that this curious fossil may be the highly specialized root of a free crinoid, "a sort of sucker-disk." "It is even possible," he says, "to think of this disk as a swimming organ." Dr. Raymond also has two papers on Trilobites, in one of which he describes a new species of *Holasaphus* and in the other some new species of Asaphidæ. The same author describes two new species of *Tetradium*, one of which is from the Lowville Beds of Ontario, but the locality and horizon of the other are not stated—a probably quite unintentional omission. Returning to the Trilobites, Dr. Raymond revises the species that have been referred to the genus *Bathyurus* and erects for some of them the new genera *Petigurus* [*sic*], *Hystricurus*, *Haploconus*, *Platycolpus*, *Plethopeltis*, *Goniurus*, and *Leiostegium*. Miss A. E. Wilson then founds a new genus of Brachiopod, *Oxoplecia*, for a species *O. calhouni*, from the base of the Utica.

The two papers under Palæobotany are by Mr. W. J. Wilson, who describes *Lebephyllum*, a new genus of Dicotyledonous plant from the Tertiary beds of Kettle River, B.C. This is based on leaves of uncertain affinity, but the name in any case should have been *Lebetophyllum*. He also describes a new species of *Lepidostrobus* from the Minto Coal-mines.

Under Mineralogy Mr. R. A. A. Johnston discusses an occurrence of Prehnite at Adams Sound, Admiralty Inlet, Baffin Island.

If this Bulletin is intended for the prompt publication of short papers it may prove very useful, but we observe that the MS. of the first two papers was transmitted in July, 1910, so, at any rate, that is not an example of promptitude.

VII.—Maryland Geological Survey.

UNDER the direction of the State Geologist, Dr. William Bullock Clark, two handsome volumes of letterpress and one of plates, on the Devonian System of Maryland, have been issued (1913). They form vols. v to vii of the series of reports dealing with the systematic geology and palæontology of the State.

Vol. V, Lower Devonian (pp. 560, with 17 text-figures and 16 plates, also 82 of fossils in atlas), opens with an instructive and interesting Introduction on the General Relations and the Paleography of the Devonian, with an Historical Review and Bibliography, by Drs. C. K. Swartz and C. Schuchert, and Professor C. S. Prosser. Attention is first drawn to the original labours of Sedgwick and Murchison, aided by Lonsdale, in the foundation of the Devonian System, but, as justly remarked, the limits of the system "were not clearly defined", and indeed with regard to the Silurian junction no evidence was to be found in Devonshire. Owing to the folded and faulted structure of the English area, the true succession of the subdivisions and their respective faunas could not be distinguished, but subsequent researches of many geologists in the Rhine Valley, in Belgium, the Ardennes, the Hartz Mountains, and in Bohemia have established the sequence on a firm basis, and it has become "the type of the Devonian System of the world".

The authors point out that the Devonian of Eastern America was first critically studied by James Hall, aided by de Verneuil, when they included the strata from the Catskill down to the Oriskany Sandstone as Devonian; while at a much later period Kayser demonstrated the Lower Devonian age of the Helderberg (Lower Helderberg of Hall), and this conclusion has been more fully confirmed by Drs. J. M. Clarke and C. Schuchert.

In a map showing the distribution of the Devonian in Maryland, and in a table in the text, the following subdivisions are recognized:—

Upper	Catskill red sandstone Formation.		
	Jennings Formation	Chemung Sandstone.	
		Parkhead Sandstone.	
		Woodmont Shale.	
		Genesee black shale.	
Middle	Romney Shale	Hamilton Shale.	
		Marcellus-black shale.	
		Onondaga Shale.	
Lower	Oriskany Sandstone	Ridgely Sandstone.	
		Shriver Chert.	
	Helderberg Limestone	Becraft member.	
		New Scotland member.	
		Coeymans member.	
		Keyser member.	

The following statements contain so much of general interest that it appears desirable to quote them at some length:—

"The Devonian of Maryland forms a part of the Appalachian Province which extends from New York southward in the Appalachian Mountains and Plateau. The resemblance of the formations to those of the northern part of the area is so close as to establish their essential identity both in lithology and fauna, and hence

the similarity of the conditions under which they were deposited, the chief difference being the development of the Keyser Limestone in Maryland, an earlier phase of the Helderberg than has hitherto been recognized in New York, and the profusion of life in the Oriskany. In Lower Devonian time the Helderberg and Oriskany seas stretched southward from New York to beyond Maryland. The Middle Devonian was ushered in by a slight deepening of the seas in Maryland, clays being deposited near the shore in Onondaga time, while limestone was formed in the open sea farther west. . . . The Upper Devonian introduces one of the most interesting chapters of the history of this period. At the beginning of Upper Devonian time a fauna appears comprising few species, one of which, *Hypothyris cuboides*, is found at such widely separated points as New York, North-Western America, the Rhine Province, Russia, and China. It seems, therefore, to have encircled the northern hemisphere in its journeys. The cuboides fauna lasted but a short time. In later Middle Devonian time the sea had deepened throughout the west in North America. The descendants of the Middle Devonian shore-loving Brachiopods of the eastern area continued to live in the shallower waters, where they received new species from the Atlantic, and by their combination formed the Ithaca fauna. The deeper waters off shore were invaded by forms that differed greatly from all that preceded them in this region. They consist chiefly of Goniatites (Cephalopods with angular sutures) and minute Pelecypods. The rarity of Brachiopods is conspicuous. This assemblage, termed by [J. M.] Clarke the Naples fauna (also known as the Intumescens fauna from its guide species, *Manticoceras intumescens*), is believed by him to have journeyed from its home in north-eastern Arctic Russia via north-western America to New York and eastward to the Rhine Valley, where it is found in a similar position, its route being indicated by the progressive development of the species. . . . As the level of the sea oscillated, leading to the interleaving of the two types of containing sediments in central New York, the Naples and Ithaca faunas migrated back and forth. That these faunas ranged southward into Maryland is shown by the occurrence of the Naples fauna in abundance in the Genesee and lower beds of the Woodmont member of the Jennings formation of the western sections and the replacement of the Naples fauna by the Ithaca fauna in the upper beds of the Woodmont member of the eastern sections, while it still continued to live in the west, indicating conditions essentially similar to those that existed in New York at this time. It results that three independent faunas coexisted in this province in early Upper Devonian time, their range being determined by the physical conditions under which they dwelt, while they migrated back and forth as these conditions varied."

Other instances of the introduction, survival, and recurrence of species are discussed; and it is pointed out that towards the close of the Devonian period the land was elevated, and the thick deposits of red clays and sands of the Catskill formation were accumulated in lakes and embayments. The strata contain macerated remains of plants and fragments of fishes. "The Devonian was finally terminated

by a subsidence of the continent, and a new invasion of the Mississippi seas introducing Lower Carboniferous time."

The Paleography of the Devonian is illustrated by a series of maps. The bulk of the volume comprises the details of the stratigraphy of the Lower Devonian rocks, and of the range and distribution of the fossils: this part is by Drs. Schuchert, Swartz, T. Poole Maynard, and R. B. Rowe. The systematic paleontology is by Drs. Schuchert, Swartz, Maynard, D. W. Ohern, E. O. Ulrich, and R. S. Bassler.

Vol. VI, Middle and Upper Devonian (pp. 720, with 2 text-figures, 6 plates, also 38 of Middle Devonian and 29 of Upper Devonian fossils in atlas). In this volume we have full particulars of the strata, of the correlation of subdivisions, the distribution and range of species, and the relations of the faunas to the sediments. The general stratigraphic and paleontologic work is by Professor Prosser, Dr. E. M. Kindle, and Dr. Swartz; the systematic paleontology of the Middle Devonian is mainly by Professor Prosser and Dr. Kindle, with contributions on Bryozoa and Ostracoda by Dr. E. O. Ulrich and Dr. R. S. Bassler; and the systematic paleontology of the Upper Devonian is by Dr. J. M. Clarke and Dr. Swartz.

The illustrations in the two volumes of text comprise effective views of formations and scenery, and a series of columnar sections. Vol. VII consists of the *Atlas of Plates*, 149 in number. Many new species are figured, while among European forms we note *Hindia sphæroidalis*, Dunc., *Favosites basalticus*, Goldf., *Halysites catenulatus*, Linn., from the Lower Devonian; *Atrypa reticularis*, Linn., from Lower, Middle, and Upper Devonian; and *Schizophoria* (*Orthis*) *striatula*, Schloth., *Spirifer disjunctus*, Sow., and *Buchiola* (*Cardiola*) *retrostriata*, v. Buch, from the Upper Devonian.

H. B. W.

VIII.—Bulletins issued by the United States Geological Survey.

Bulletin 521. The Commercial Marbles of Western Vermont. By T. Nelson Dall. pp. 170, with 17 plates (including 2 maps) and 25 figures in the text. 1912.—There is already an extensive literature on the geology of the 'marble belt' of Western Vermont, and the present bulletin is designed to summarize the previous work, providing those interested in the marble industry with a clear idea of the geological structure of the district and of the microscopic structures of the various marbles. In describing the relations of the calcite to the dolomite in the area, the author points out that repeated alternations of calcite and dolomite bands are frequent: this can only be explained by assuming repeated changes in the conditions of sedimentation to have taken place. The mineral constituents and microstructure of the marbles are described, and are illustrated by numerous text-figures, and a clear account is given of the geological structure of the area. There is a useful glossary of technical terms and a good index.

Bulletin 522. Portland Cement Materials and Industry in the United States. By Edwin C. Eckel, with contributions by F. Burchard and others. pp. 401, with 19 maps and 2 diagrams. 1913.

Parts i and ii of this report describe the chemical and physical properties of Portland cement materials, but the greater part of the book deals with the cement resources of individual States. This involves a description of the main occurrences of limestone, chalk, and shell-marl in the United States. It is shown that the value of the raw materials depends on their location with respect to fuel, transportation routes and markets, and, accordingly, these points are considered in each case. The distribution of the materials is illustrated by geological maps wherever possible. Short bibliographies are given under the several States, and there is a good general bibliography, which has been compiled by F. Burchard.

Bulletin 527. Ore Deposits of the Helena Mining Region, Montana. By Adolph Knopf. pp. 143, with 7 plates (including 2 maps) and 4 figures in the text. 1913.—The detailed description of the mining districts of the Helena region, which occupies the greater part of this bulletin, is preceded by a clear sketch of the geology of the region as a whole. The ore-deposits are silver-lead and gold-silver deposits, and they belong to two distinct periods of ore-deposition, following two periods of marked igneous activity in the area. The older group of lodes and veins followed the intrusion in late Cretaceous time of a great mass of quartz-monzonite forming the northern extension of the Boulder batholith. These are all tourmaline-bearing lodes, the ore consisting principally of galena associated with sphalerite and pyrite. This appears to be the first recorded occurrence of silver-lead ores associated with tourmaline. Analyses and field evidence show that the tourmaline and the sulphides travelled together: they were probably derived from the quartz-monzonite magma, but the introduction of the ore took place distinctly later than the intrusion of the quartz-monzonite and of its associated aplites. The second period of ore-deposition followed the extrusion of a group of dacites of Upper Miocene age, and of a group of rhyolites, probably slightly younger than the dacites. The ores of this period are found in fissure veins, characterized by the presence of cryptocrystalline quartz with a subordinate quantity of sulphides. They are worked for their gold and silver contents. These are low-temperature ore-deposits, while the older group, characterized by tourmaline, were deposited at a *relatively* high temperature. Numerous analyses are given of samples taken from veins of both groups occurring in quartz-monzonite, and interesting comparisons are made between the metasomatic processes which operated during the two periods of mineralization.

Bulletin 529. The Enrichment of Sulphide Ores. By W. Harvey Emmons. pp. 260. 1913.—The theory of enrichment of sulphide ores, first put forward in 1900, has been found to have very wide application, and has proved to be of considerable value in the development of sulphide deposits. It is a theory which lends itself especially to research in the laboratory, and though much work has been done, there are many problems which still remain unsolved. This bulletin summarizes our present knowledge of the subject; it supplies some new material and suggests lines for further inquiry. The bearings of physical conditions on the enrichment of deposits are

discussed. The chemistry of enrichment is considered: firstly in the light of experimental data; secondly from considerations of the composition of mine waters, thirty-seven samples having been analysed. Very valuable are the contributions on the chemical relations and occurrence of the minerals of copper, silver, gold, lead, zinc, and iron, and of certain gangue minerals, including felspars, kaolin, sericite, alunite, sulphates, and carbonates. There is a brief review of the several classes of sulphide deposits in the States, and a detailed review of the various mining districts. While having very important bearing on the economic side of mining geology, the bulletin forms a valuable contribution to the mineralogical chemistry of the sulphide minerals.

IX.—Probable Origin of the African Elephant.

W. O. Dietrich.—Zur Stammesgeschichte des afrikanischen Elephanten. Zeitsch. f. induktive Abstammungs- und Vererbungslehre, vol. x, p. 49, with 7 text-figures, 1913.

IN this paper the author discusses the probable origin of the African Elephant. He first points out how very little material there is at present upon which to base an opinion, and gives a useful list of the principal discoveries. He then discusses at some length the chief dental characters which are of importance in determining relationships within the group. From the nature of its tooth structure he concludes that the African Elephant, while in some respects highly specialized, is an archaic type, and expresses his belief that its primitive characters cannot be the result of retrogressive changes in a more advanced type such as *Elephas antiquus*, but on the other hand prove an independent descent from some at present unknown type of Mastodon. It is important to note, however, that although a Mastodon has been recorded from South Africa, all the true elephants at present known from deposits of Pliocene or Pleistocene age in Africa (the Sudan, Zululand, and recently British East Africa) possess teeth of a more specialized type than those of *E. africanus*. It seems, therefore, by no means certain that this species may not have acquired the peculiar characters of its dentition as a result of retrogressive changes, possibly in consequence of some peculiarity in its food.

A table is given, showing at a glance the various views that have been expressed on this subject.

C. W. A.

X.—Brief Notices.

1. Wisconsin Geological and Natural History Survey. — An instructive work on "The Geography and Industries of Wisconsin", by Professor R. H. Whitbeck, has been issued by this survey (Bulletin No. xxvi, Educational Series, No. 3, 1913). The mineral industries include, in order of importance, iron-ore, zinc-ore, stone, clay, mineral water, lime, sand, and lead-ore. The annual output is valued at about twenty million dollars. No coal occurs, the bed-rocks being all older than any coal-bearing formations. In the value of commercial mineral waters Wisconsin is foremost among the States. More

than six million gallons from the mineral springs of Waukesha are sold annually. More important, however, are the other sources of wealth. The forest industries are stated to have yielded "far more wealth than the gold-mines of California"; in agricultural industries Wisconsin ranks about tenth in States for the annual value of farm products: the soils due mostly to glacial drifts are generally fertile, while the manufacturing industries include lumber, metal-work, farm produce, leather, etc. The work is illustrated by maps, diagrams, and photographic views of mine-works, quarries, forest, and logging scenes, soil formation, farm and fruit lands, etc.

2. Mount Lyell Copper District of Tasmania.—On this subject an important article has been published by Messrs. C. G. Gilbert and J. E. Pogue (Proc. U.S. Nat. Mus., vol. xlv, No. 2005, p. 609, 1913). The authors deal with the Mount Lyell and North Mount Lyell Mines: the former yields chalcopyrite, etc.; the latter yields bornite predominantly, with chalcocite, also tetrahedrite and chalcopyrite. The history and geology of the area receive due attention, and the authors discuss the paragenesis and secondary enrichment of the ore-deposits.

REPORTS AND PROCEEDINGS.

Geological Society of London.

December 17, 1913.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

At the conclusion of a paper entitled a "Supplementary Note on the Discovery of a Palæolithic Human Skull and Mandible at Piltdown (Sussex)", by Charles Dawson, F.S.A., F.G.S., and Arthur Smith Woodward, LL.D., F.R.S., Sec.G.S., an Appendix by Professor Grafton Elliot Smith, M.A., M.D., V.P.R.S., was inadvertently omitted from the report published last month (see pp. 44–5). Professor Elliot Smith pointed out that the presence of the anterior extremity of the sagittal suture, which hitherto had escaped attention, had enabled him to identify a ridge upon the cranial aspect of the frontal bone as the metopic crest, and thus to determine beyond all question the true median plane. It is 21 mm. from the point of the large fragment (in the frontal region). Mr. F. O. Barlow called his attention to the fact that the contour of the frontal bone when viewed in norma facialis confirms this identification of the median plane, because the summit of the curve is directly above the endocranial metopic crest. Professor J. T. Wilson pointed out to him that the direction of the orbital plate of the frontal bone is such that it assumes its proper position only when the fragment is so placed that the above-mentioned crest is in the median plane. The backward prolongation of the frontal median crests cuts the parietal fragment precisely along the line determined by Dr. Smith Woodward on other grounds. It indicates that the posterior part of the sagittal suture is obliterated—a view that is confirmed by the presence of an irregular wavy furrow upon the bone, precisely similar to that found in other skulls where this suture had recently closed. This may occur in modern man at

any time between about 30 and 40 years of age. The evidence afforded by the parasagittal ridge on the left parietal, by the meningeal grooves, and by the positions occupied by the fragments of the lambdoid suture upon the occipital and parietal fragments, corroborates the correctness of this identification of the median plane.

CORRESPONDENCE.

THE FREEZING OF SURFACE SOIL.

Sir,—In *Nature* for 1911 I described the occurrence of tooth-like projections of fibrous ice which formed on exposed pieces of chalk partly buried in the soil. Here the water had not frozen *in* the chalk but *on* the surface, fresh supplies of water coming from below through the capillaries of the stone to freeze at the surface. Each pore would seem to have produced a separate crystal fibre, the fibres from each pore adhering to one another and resembling fibrous gypsum in appearance. Occasionally when the supply of water from below varied over the chalk surface, strains were set up by the irregular growth of the 'ice-teeth', which caused the mass to split along the fibres and grow in spiral forms. The amount of ice produced was several times greater than the volume of the chalk upon which it formed, showing that the water had passed from the wet ground through the chalk and frozen on the surface.

Since describing the above I have seen a "Note on the action of Frost on Soil", by Milner Roberts, in the *Journal of Geology*, vol. xi, pp. 314–17. He says, "The action of frost in altering the surface of the soil was well shown during the period of cold weather which prevailed over the Puget Sound district from February 10 to 18, 1903.

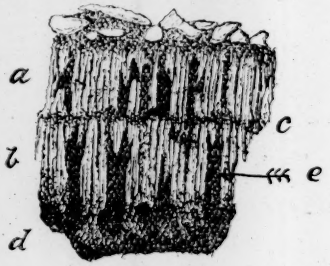
"The first night's frost had its usual effect of raising the surface of loose ground, which was well illustrated by gravelly soil. A layer of ice consisting of vertical prisms five-eighths of an inch long formed during the night at a depth of about five-eighths of an inch below the surface, thus raising the overlying material without otherwise disturbing it. The cold of the following night produced a similar layer of ice almost an inch thick below the first one, raising the latter along with its load of sand and gravel.

"The following conditions prevailed and seem to have controlled the formation of these many storied forms: (1) ground which was not frozen and which was readily permeable to moisture; (2) freezing temperature at night; (3) mild thawing in the daytime; and (4) considerable moisture in the soil."

During the present week similar conditions have prevailed here, and similar effects have been produced on a gravel walk. In the Figure, p. 96, which is full size, *a* and *b* are two layers of fibrous ice resting upon wet clayey soil *d*. During the first night's frost the pebbles and some soil were lifted. On the following night the layer of ice *b* was formed. It, however, raised with it a thin layer of soil *c*. Particles of soil were scattered throughout the ice, having been detached from the soil below and lifted by the growing ice fibres.

This growth of ice was not regular over the whole surface, for here and there pits and grooves were left in the gravelly surface. Examination also showed that there were numerous cavities *e* in the fibrous ice layers, resulting from the local failure of the water supply from below.

The segregation of the water to form ice layers when the surface of the ground freezes not only seems to have a bearing upon the question of the flow of the frozen soil-cap downhill, but also serves to explain the peculiar arrangement of the stones at or near the surface, especially in high latitudes. It has been remarked by many that in frigid climates the stones and other objects on the ground stand with their longer axes in a vertical position.



During the melting of the ice layers below the surface stones would subside irregularly, slipping on end into the cavities and channels formed by the melting of the ice below. When it is remembered that the formation of ice layers beneath the surface and their melting must take place very frequently in high latitudes, the positions of the stones near the surface must be moved with regard to each other very often. In this movement we have a cause which appears to be capable of producing the peculiar vertical arrangement of the stones near the surface.

Such a vertical arrangement of the longer axes of the stones may be seen in the upper surfaces of many of the high-level river gravel terraces of England, but not in the lower gravels. It is common in the high-level river gravel terraces of the Trent, where signs of disturbance often extend downwards many feet from the surface.

R. M. Deeley.

MISCELLANEOUS.

Munificent Bequests in aid of Science.—Dr. Tempest Anderson, who died on board ship in the Red Sea on August 26 last year, has left £50,000 to the Yorkshire Philosophical Society, of which he was formerly president; and £25,000 to the Percy Sladen Memorial Fund, established by his sister, Mrs. Sladen, in 1904.

Geological Survey.—The President of the Board of Education has promoted Mr. G. W. Lamplugh, F.R.S., to the post of Assistant Director (for England and Wales) on the Geological Survey of Great Britain, and Mr. T. C. Cantrill to that of District Geologist. The appointments took effect on January 6, 1914.